Universidade de São Paulo
Faculdade de Saúde Pública

Impacto da aquisição de alimentos ultraprocessados e da carne bovina sobre a agrobiodiversidade no Brasil (2017-18)

Fernanda Helena Marrocos Leite Villamarin

Tese apresentada ao Programa de Pós-Graduação em Saúde Global e Sustentabilidade para obtenção do título de Doutor em Ciências.

Área de concentração: Saúde Global e Sustentabilidade

Orientador: Prof. Tit. Carlos Augusto Monteiro
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Dedico este trabalho à minha família, em especial ao meu companheiro, Fernando, e à minha filha, Liz.

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"Sentimo-nos como se estivéssemos soltos num cosmos vazio de sentido e desresponsabilizados de uma ética que possa ser compartilhada, mas sentimos o peso dessa escolha sobre as nossas vidas. Somos alertados o tempo todo para as consequências dessas escolhas recentes que fizemos. E se pudermos dar atenção a alguma visão que escape a essa cegueira que estamos vivendo no mundo todo, talvez ela possa abrir a nossa mente para alguma cooperação entre os povos, não para salvar os outros, mas para salvar a nós mesmos. "

Ideias para adiar o fim do mundo, Ailton Krenak

RESUMO

Leite FHM. Impacto da aquisição de alimentos ultraprocessados e da carne bovina sobre a agrobiodiversidade no Brasil (2017-18). [Tese de doutorado]. São Paulo: Faculdade de Saúde Pública, Universidade de São Paulo; 2023.

Introdução: A agrobiodiversidade é recurso essencial para a promoção de dietas e sistemas alimentares saudáveis e sustentáveis. Apesar disso, a agrobiodiversidade global está em declínio, especialmente a diversidade de espécies vegetais utilizadas para consumo humano. Objetivo: Esta tese buscou estudar a agrobiodiversidade mobilizada pela aquisição domiciliar de alimentos no Brasil e a influência que padrões de aquisição de alimentos ultraprocessados e de carne bovina exercem sobre a agrobiodiversidade. Métodos: Estudo transversal em que foram analisados dados da Pesquisa Nacional de Orçamentos Familiares 2017-18 a fim de estimar a quantidade total de alimentos adquiridos. Agregados de domicílios (n=575) foram utilizados como unidade de análise do estudo. Os itens alimentares adquiridos foram classificados segundo a classificação Nova. Metodologia inédita de quatro passos foi aplicada para estimar a diversidade de espécies subjacentes às aquisições domiciliares de alimentos. O índice de Shannon foi utilizado para avaliar a diversidade de espécies vegetais mobilizadas. Modelos de regressão linear foram utilizados para testar associações entre a participação da carne bovina e de alimentos ultraprocessados no total adquirido e o índice de Shannon. O primeiro manuscrito apresenta as hipóteses desta tese e ressalta a ausência do debate a respeito dos efeitos dos alimentos ultraprocessados sobre a agrobiodiversidade nas agendas internacionais de sistemas alimentares, biodiversidade e mudanças climáticas. O segundo manuscrito descreve a abordagem metodológica utilizada para estimar a agrobiodiversidade demandada pela dieta, bem como aplicar esta abordagem em dados de aquisição de alimentos no Brasil. O terceiro manuscrito descreve a diversidade de espécies vegetais mobilizadas pela população brasileira, além de investigar o impacto de diferentes padrões de aquisição (de ultraprocessados e de carne bovina) sobre a diversidade de espécies vegetais mobilizadas. Resultados: Mais de 95% da quantidade total de espécies vegetais mobilizadas pela aquisição domiciliar de alimentos no Brasil foram provenientes de apenas seis espécies:

braquiária, milho, soja, arroz, cana-de-açúcar e trigo. O valor médio do índice de Shannon relativo à diversidade de espécies vegetais mobilizadas foi de 0,86 indicando baixa diversidade. Os efeitos simultâneos da participação de alimentos ultraprocessados e da carne bovina no total adquirido sobre a diversidade de espécies vegetais mobilizadas mostraram que os valores médios ajustados do índice de diversidade diminuíram significativamente em todos os cenários de aquisição de alimentos ultraprocessados com o aumento da participação de carne no total adquirido. De forma semelhante, o índice de Shannon tendeu a diminuir significativamente em todos os cenários de aquisição de carne bovina com aumento da participação de ultraprocessados no total adquirido, com exceção do último quinto de participação da carne bovina ($p>0,05$). O índice de Shannon caiu pela metade (51%) passando de um cenário com menor participação de ultraprocessados e de carne bovina (1,22) para um cenário com a maior participação de ambos os grupos (0,60). Conclusões: Os resultados deste estudo demonstram uma baixa diversidade de espécies vegetais mobilizadas por agregados de domicílios brasileiros, com alta concentração em um número muito reduzido de espécies. Observou-se piora da diversidade de espécies mobilizadas com o aumento da participação de alimentos ultraprocessados e da carne bovina.

Palavras-chave: Agrobiodiversidade. Alimento ultraprocessado. Carne bovina. Índice de Shannon. Aquisição domiciliar de alimentos. Brasil.

ABSTRACT

Leite FHM. [Impact of ultra-processed food and beef acquisition on agrobiodiversity in Brazil (2017-18)]. [Thesis]. São Paulo: Faculdade de Saúde Pública, Universidade de São Paulo; 2023. Portuguese.

Introduction: Agrobiodiversity is key for promoting healthy diets and moving towards more sustainable food systems. Despite this, global agrobiodiversity is declining, especially the diversity of plant species used for human consumption. Objective: This thesis aims to study the agrobiodiversity mobilized by household food acquisition in Brazil and the influence that ultra-processed food and beef acquisitions might exert on agrobiodiversity. Methods: Cross-sectional study in which data from the 2017-18 National Household Budget Survey were used to quantify the total amount of foods purchased. Household aggregates (n=575) were used as the unit of analysis. All food items were classified according to the Nova classification system. A sequential, four-step approach was applied to estimate the plant species underlying household food acquisitions. The Shannon index was used to evaluate the diversity of plant species mobilized. Linear regression models were used to test associations between the share of beef and of ultra-processed foods in total food acquisition and the Shannon index. The first manuscript presents the hypotheses of this thesis and highlights the lack of debate around the effects of ultra-processed foods on agrobiodiversity in global food systems fora, biodiversity conventions and climate change conferences. The second manuscript describes the methodological approach used to estimate the agrobiodiversity linked to human diet, and applies this approach to Brazilian food purchase data. The third manuscript describes the diversity of plant species mobilized by the Brazilian population, and investigates the impact of different food acquisition patterns (with a focus on ultra-processed foods and beef) on the diversity of plant species mobilized. Results: More than 95% of the total amount of plant species required by Brazilian household food acquisitions came from only six species - brachiaria, maize, soybean, rice, sugarcane and wheat. The average Shannon index relative to the diversity of plant species that underlie household food acquisitions in Brazil was 0.86, indicating low diversity. Adjusted mean values of the diversity index decreased significantly as the share of beef to total food acquisition increased, in all scenarios of ultra-processed food acquisition. Similarly, the Shannon index tended to significantly decrease with an increase in the share of ultra-processed foods to total food acquisition in all scenarios of beef acquisition, except in the fifth quintile of beef ($p>0.05$). The Shannon index decreased by half (51%) moving from a scenario with the lowest share of both ultra-processed foods and beef to total food acquisition (1.22) to a scenario with the highest share of both food groups (0.60). Conclusion: Our findings demonstrate a low diversity of species mobilized by Brazilian household aggregates and a high concentration in a small number of species. The diversity of species mobilized decreased with an increase in both the share of ultra-processed foods and of beef in total food acquisitions.

Keywords: Agrobiodiversity. Ultra-processed food. Beef. Shannon index. Household food purchase. Brazil.

SUMÁRIO

APRESENTAÇÃO

O Guia alimentar para a População Brasileira, publicado em 2014 pelo Ministério da Saúde, foi um dos primeiros Guias Alimentares no mundo a reconhecer os potenciais impactos da produção e do consumo de alimentos ultraprocessados e de produtos de origem animal sobre o meio ambiente, incluindo a biodiversidade. Porém, apesar do caráter inovador do Guia em incluir a sustentabilidade em suas recomendações, mais estudos eram necessários com intuito de gerar evidências científicas a respeito dos impactos ambientais da dieta brasileira e avançar nas discussões e agendas políticas atreladas a esta temática. Sendo assim, o Núcleo de Pesquisas Epidemiológicas em Nutrição e Saúde da Universidade de São Paulo (NUPENS/USP), unidade acadêmica que coordenou a produção do Guia, iniciou duas novas linhas de pesquisa sobre os impactos ambientais do consumo de alimentos ultraprocessados e de produtos de origem animal (principalmente a carne bovina): uma sobre emissões de carbono e uso do solo e da água, e outra sobre a agrobiodiversidade. Esta tese inaugura esta segunda linha de pesquisa no NUPENS/USP, a partir do meu ingresso no curso de doutorado em 2019.

A presente tese buscou avaliar o impacto da aquisição domiciliar de alimentos sobre a agrobiodiversidade no Brasil no período de 2017-18, com foco na influência da aquisição de alimentos ultraprocessados e da carne bovina, e é composta por sete capítulos. O primeiro capítulo apresenta o referencial teórico que fundamentou este estudo, em especial as principais características da transição alimentar observada em escala global que podem estar contribuindo para a perda da agrobiodiversidade, bem como a incipiência de metodologias e métricas capazes de determinar a agrobiodiversidade mobilizada pela dieta humana.

O segundo capítulo explicita os objetivos da tese. A concretização desses objetivos está apresentada em três manuscritos elaborados, majoritariamente, a partir da análise de dados de aquisição domiciliar de alimentos, coletados na Pesquisa de Orçamentos Familiares (POF) conduzida entre julho de 2017 e julho de 2018 pelo Instituto Brasileira de Geografia e Estatística (IBGE). O terceiro capítulo traz uma relação entre os manuscritos elaborados.

O quarto capítulo consiste no manuscrito "*Ultra-processed foods should be central to global food systems dialogue and action on biodiversity*" (em inglês), elaborado com o intuito de apresentar brevemente as hipóteses desta tese e ressaltar a ausência completa do debate a respeito dos efeitos catastróficos do consumo aumentado de alimentos ultraprocessados sobre a agrobiodiversidade nas agendas internacionais de sistemas alimentares, biodiversidade e mudanças climáticas. Este artigo foi publicado no periódico *BMJ Global Health* em março de 2022. A publicação deste documento culminou em sete entrevistas concedidas a diferentes veículos de comunicação nacionais e internacionais, incluindo: Agência Bori, *ZME Science*, GIZMODO Brasil, Jornalismo Júnior ECA-USP, Programa Trocando em Miúdos, *News Medical* e Repórter Eco – TV Cultura.

O quinto capítulo consiste no manuscrito "*Methodology for determining the agrobiodiversity that underlies human diets: an application using Brazilian food purchase data*" (em inglês), que descreve a abordagem metodológica desenvolvida como parte desta tese com o objetivo de determinar a agrobiodiversidade demandada pela dieta humana, bem como aplicar esta abordagem em dados de aquisição domiciliar de alimentos no Brasil. Este artigo foi submetido para publicação no periódico *BMJ Global Health*. Resultados decorrentes deste estudo foram apresentados no congresso 17th *World Congress on Public Health,* realizado em 2023 em Roma.

O sexto capítulo consiste no manuscrito *"Diversity of plant species mobilized by household food acquisitions in Brazil (2017-18): influence of the purchase share of beef and ultra-processed foods"*, que descreve a diversidade de espécies vegetais subjacentes às aquisições domiciliares de alimentos no Brasil, além de investigar o impacto de diferentes padrões de aquisição de alimentos ultraprocessados e de carne bovina sobre a diversidade de espécies vegetais mobilizadas por domicílios brasileiros. Este artigo será submetido ao periódico *Nature Sustainability*. Resultados oriundos deste estudo foram apresentados no XXVII Congresso Brasileiro de Nutrição, realizado em 2022 em Maceió; na *SCORAI-ERSCP-WUR Conference* realizada em 2023 na Holanda; e no *XX Congreso Latinoamericano de Nutrición* (SLAN), realizado em 2023 no Equador.

O sétimo e último capítulo da tese apresenta as considerações finais, incluindo as principais implicações diante dos achados nos estudos para o debate a respeito da promoção de dietas e sistemas alimentares mais saudáveis e sustentáveis, e conservação da agrobiodiversidade.

1. INTRODUÇÃO

1.1 AGROBIODIVERSIDADE E SEU PAPEL NA PROMOÇÃO DE DIETAS E SISTEMAS ALIMENTARES MAIS SAUDÁVEIS E SUSTENTÁVEIS

A biodiversidade do planeta é uma pré-condição para a preservação de recursos naturais e da vida, enquanto um dos seus mais importantes componentes, a agrobiodiversidade (ou biodiversidade agrícola) – a qual, por sua vez, é definida como "a variedade e variabilidade de animais, plantas e microrganismos usados direta ou indiretamente para alimentação e agricultura (Ex.: lavouras, rebanhos, pesca), compreendendo as espécies utilizadas como alimento, forragem, fibra, combustível e fins farmacêuticos; espécies não colhidas que apoiam a produção agrícola (Ex.: predadores, polinizadores), bem como as do ambiente mais vasto que apoiam os ecossistemas (Ex.: agrícolas, pastorais, florestais e aquáticos)"(1) – é recurso essencial para a promoção de sistemas alimentares e padrões alimentares mais saudáveis e sustentáveis(2, 3).

A agrobiodiversidade é resultado de processos de seleção natural (Ex.: adaptação às mudanças nos padrões climáticos ou a partir de características específicas do solo) que têm sido entrelaçados com o manejo cuidadoso e o desenvolvimento inventivo de agricultores, habitantes das florestas, caçadores-coletores, pastores e pescadores ao longo de milênios (Ex.: seleção pelo sabor, facilidade de processamento ou colheita)(3). Quando gerida adequadamente e com base no conhecimento cultural e ancestral das populações tradicionais, a agrobiodiversidade é capaz de fornecer recursos e processos incorporados nos sistemas agrícolas, de forma a permitir que esses sistemas não apenas satisfaçam as necessidades alimentares e nutricionais atuais, mas exerçam um impacto negativo mínimo no ambiente, além de gerar múltiplos serviços ecossistêmicos, como adaptação a mudanças climáticas, proteção do solo, polinização, controle de pragas, entre outros(1, 3, 4).

Para além dos múltiplos serviços ecossistêmicos, a agrobiodiversidade também exerce papel fundamental na promoção de dietas mais saudáveis. De modo geral, o consumo de um número diversificado de espécies, bem como de suas variedades, tem sido associado a uma melhor qualidade da dieta e uma melhor adequação no consumo de nutrientes (exceto nutrientes a serem limitados)(5, 6). Nesse sentido, os Guias alimentares ao redor do mundo, incluindo o Guia Alimentar para a População Brasileira(7), recomendam o consumo de uma diversidade de alimentos, principalmente aqueles *in natura* ou minimamente processados de origem vegetal(6).

Segundo o Guia Alimentar (7, p. 49)

> Alimentos *in natura* ou minimamente processados, em grande variedade e predominantemente de origem vegetal, são a base de uma alimentação nutricionalmente balanceada, saborosa, culturalmente apropriada e promotora de um sistema alimentar socialmente e ambientalmente sustentável.

Apesar do papel crucial da agrobiodiversidade para a segurança alimentar e nutricional, para a diversificação e saudabilidade das dietas e para a resiliência dos sistemas alimentares, cada vez mais se observa uma perda acelerada e inédita no número de espécies utilizadas para alimentação humana(1, 8). Tal processo se intensificou com a chamada Revolução Verde e a consequente monotonia das paisagens agrícolas e redução na variedade genética dos animais(4). Por exemplo, das mais de 7 mil espécies de plantas comestíveis identificadas e utilizadas para alimentação humana desde a origem da agricultura(9), menos de 200 espécies tiveram produção significativa em 2014, e apenas 9 culturas representaram mais de 66% em peso de toda a produção agrícola(1). Essa homogeneização do sistema alimentar global(10) tem sido associada às diferentes formas da má nutrição, dentre as quais se destaca a desnutrição, as deficiências de micronutrientes e/ou sobrepeso/obesidade, e às doenças crônicas não transmissíveis (DCNTs) causadas pela má alimentação (como doenças cardiovasculares, diabetes tipo 2 e diferentes tipos de câncer)(11, 12).

1.2 DIETAL GLOBAL E PERDA DA AGROBIODIVERSIDADE

Duas características principais da transição alimentar observada em escala global nas últimas décadas poderiam contribuir para reduzir o número de espécies demandadas pela alimentação humana. A primeira está relacionada à substituição crescente de padrões tradicionais de alimentação baseados em alimentos *in natura* ou minimamente processados e suas preparações culinárias por padrões baseados no consumo de alimentos ultraprocessados(13, 14) – ou seja, formulações de ingredientes, em sua maioria de uso industrial, que contêm pouco ou nenhum alimento integral e tipicamente adicionados de corantes, aromatizantes e outros aditivos cosméticos (15). Enquanto os primeiros tendem a demandar uma grande diversidade de alimentos, variando entre os territórios e ao longo das estações do ano, os padrões baseados em alimentos ultraprocessados implicam a demanda por um número reduzido de espécies vegetais de alta produtividade (Ex.: soja, milho, trigo, cana-de-açúcar), que são industrialmente processadas com o intuito de fornecer ingredientes utilizados na confecção daqueles produtos(13, 16, 17). Tal fato se torna preocupante, já que o consumo desses produtos tem aumentado em todas as regiões do mundo e mais rapidamente em países de renda média e baixa(18). No Brasil, a participação de alimentos ultraprocessados na aquisição domiciliar de alimentos aumentou significativamente nas últimas décadas, passando de 14,3% do total de calorias em 2002-03 para 17,3% em 2008-09 e para 19,4% em 2017-18(19).

A segunda característica corresponde à transição de padrões de consumo nos quais predominam alimentos de origem vegetal, frequentemente disponíveis na natureza em grande diversidade, por aqueles em que predominam alimentos de origem animal (incluindo a carne bovina)(20, 21), de modo geral oriundos de sistemas produtivos nos quais os animais se alimentam de pastagens pouco diversas e/ou rações, cujos ingredientes igualmente são formulações de macronutrientes (carboidratos, proteínas e gorduras), obtidos de um número reduzido de espécies vegetais de alta produtividade(13). Estudo desenvolvido por Fortes et al.(22) verificou que a produção de 1kg de carne bovina desossada produzida a partir dos sistemas produtivos predominantes no território brasileiro mobiliza cerca de 104kg de alimentação animal proveniente de apenas seis espécies: braquiária (forrageira mais prevalente no território brasileiro, representando 85% dos pastos do país) e outras espécies de alta produtividade (milho, soja, algodão, sorgo e trigo), utilizadas como rações. Na média global, a demanda alimentar por alimentos de origem animal aumentou mais de 40kg/pessoa/ano nos últimos 25 anos(21). Vale destacar que esse número esconde variações substanciais entre regiões e em relação a tipos de produtos de origem animal(21). Entre 2000 e 2011, a produção global de carne bovina aumentou, respectivamente 11%, o que foi propiciado, principalmente, pelo aumento no número de animais(21). No Brasil, a participação de carne bovina na aquisição domiciliar de alimentos aumentou significativamente nas últimas décadas, passando de 3,3% do total de calorias em 2002-03 para 4,3% em 2008-09 e para 4,4% em 2017-18(19).

É importante destacar que tais mudanças na dieta global foram impulsionadas, principalmente, pela industrialização dos sistemas alimentares, pelas mudanças tecnológicas e pela globalização, incluindo a expansão e o crescente poder de mercado e político das empresas transnacionais de alimentos e bebidas, bem como das suas redes globais de fornecimento e produção(18). Além disso, a monotonia do sistema agroalimentar foi impulsionada por programas agrícolas e políticas públicas que direcionaram esforços em pesquisa e investimentos financeiros voltados a um número restrito de lavouras de alta produtividade(23, 24), utilizadas tanto na manufatura de formulações de macronutrientes dirigidas para consumo humano (‘alimentos ultraprocessados’) quanto para consumo animal (‘rações animais’).

Para além do potencial de perda da agrobiodiversidade, aumentos no consumo de alimentos ultraprocessados e de alimentos de origem animal têm também o potencial de aumentar emissões de carbono, de degradar o solo e de pressionar reservas hídricas a depender dos sistemas produtivos predominantes(17, 25, 26), além de estarem associadas ao risco aumentado de doenças crônicas não transmissíveis de grande relevância epidemiológica, como obesidade, doenças cardiovasculares e diferentes tipos de câncer, quando consumidos em excesso(26, 27). Fazendo referência ao potencial dano que o consumo de alimentos ultraprocessados e de carnes (principalmente as carnes vermelhas) representa para a agrobiodiversidade e para os recursos naturais e seu impacto sobre a saúde humana, o Guia Alimentar para a População Brasileira incluiu, em suas recomendações, “evitar o consumo de alimentos ultraprocessados e reduzir o consumo de carnes”(7).

1.3 METODOLOGIAS E MÉTRICAS CAPAZES DE ESTIMAR A AGROBIODIVERSIDADE DA DIETA

O relatório publicado em 2019 pela Organização das Nações Unidas para a Alimentação e Agricultura (FAO) "*The State of the World's Biodiversity for Food and Agriculture*" (em inglês) destaca a necessidade urgente de se estabelecerem novas métricas e sistemas de monitoramento da biodiversidade, incluindo a agrobiodiversidade(1). A investigação da agrobiodiversidade demandada pela dieta humana é um primeiro passo importante para gerar evidências sobre os efeitos dos diferentes padrões alimentares na diversidade de espécies animais e vegetais (selvagens ou cultivadas) utilizadas para alimentação e agricultura, contudo metodologias e métricas capazes de avaliar tal influência ainda são incipientes.

Estudos anteriores conduzidos com o intuito de relacionar a agrobiodiversidade e a dieta humana concentraram-se, principalmente, em duas principais abordagens metodológicas.

A primeira foca na estimativa da biodiversidade alimentar, ou seja, a diversidade de plantas, animais e outros organismos selvagens/cultivados diretamente consumidos(28-32). Nesse sentido, dois estudos realizados no Brasil utilizando dados representativos da população brasileira, incluindo dados de aquisição domiciliar de alimentos (coletados ao longo de 7 dias consecutivos) e dados de consumo alimentar individual (coletados por meio de dois recordatórios de 24 horas), verificaram que apenas 0,7% e 1,3% da população brasileira, respectivamente, consumiam alimentos biodiversos(31) e alimentos subutilizados(32). Apesar da importância de se desenvolverem pesquisas, políticas e ações para promover o consumo de espécies subutilizadas para a conservação e restauração da biodiversidade – conforme enfatizado no Quadro Global de Biodiversidade de *Kunming-Montreal* (GBF) adotado durante a décima quinta reunião da Conferência das Partes (COP 15)(33) –, há uma necessidade urgente de se considerar também os efeitos da monotonia dos sistemas produtivos e dos padrões alimentares atuais na agrobiodiversidade(13). Isto é, embora a biodiversidade alimentar tenha o potencial de capturar a diversidade alimentar ao nível taxonômico mais baixo (ou seja, ao nível das espécies em vez de grupos alimentares)(34), essa estimativa, por si só, não é capaz de investigar os efeitos da agrobiodiversidade das dietas humanas, uma vez que não leva em consideração a diversidade de espécies subjacentes ao consumo alimentar, como, por exemplo, as que são utilizadas como pastagem/ração animal no ciclo de vida de animais de criação.

A segunda abordagem metodológica mais amplamente utilizada investiga a relação entre a biodiversidade agrícola (Ex.: diversidade de espécies vegetais e animais cultivadas/criadas) e a diversidade alimentar (mensurada por meio de indicadores como Escore de Diversidade da Dieta, Escore de Variedade da Dieta e com base em um número de grupos alimentares específicos), especialmente de pequenos agricultores e populações vulneráveis em países de renda média e baixa(35-40). De modo geral, os estudos que utilizaram essa abordagem verificaram uma associação positiva (ainda que pequena) entre a diversidade de espécies cultivadas/criadas e a diversidade alimentar de agricultores familiares, e de outros grupos populacionais, como mulheres em idade reprodutiva e crianças(41). Todavia os estudos que utilizaram tal abordagem também apresentam algumas limitações: 1) de maneira geral, não são capazes de capturar a variabilidade ao nível das espécies (haja vista que a maioria dos estudos se concentrou na diversidade de grupos alimentares específicos consumidos por uma dada população); 2) não levam em conta a variedade de espécies utilizadas em alimentos industrializados que apresentam múltiplos ingredientes (Ex.: alimentos processados e ultraprocessados); 3) investigam as associações entre diversidade alimentar e diversidade agrícola sem avaliar os efeitos que diferentes padrões alimentares (baseados em critérios diferentes da diversidade de grupos alimentares) exercem sobre a agrobiodiversidade. Por exemplo, padrões alimentares ricos em alimentos ultraprocessados podem exercer efeitos diferentes na agrobiodiversidade quando comparado àqueles ricos em alimentos *in natura* ou minimamente processados de origem vegetal(13). Um dos aspectos que tem limitado a investigação dos impactos ambientais dos alimentos ultraprocessados, incluindo os impactos sobre a agrobiodiversidade, é o fato de a maioria desses produtos conter múltiplos ingredientes e as quantidades exatas destes nem sempre serem apresentadas na lista de ingredientes ou disponibilizadas pelos fabricantes(42).

A escolha de uma métrica apropriada, capaz de avaliar a diversidade de espécies em uma amostra, também tem sido apontada como um fator limitante desta investigação. Segundo Hanley-Cook et al.(3434), a biodiversidade é geralmente dividida em três componentes sinérgicos: riqueza, uniformidade e disparidade. Por exemplo, a métrica "Riqueza de espécies" vem sendo utilizada com intuito de investigar a diversidade de espécies diretamente consumidas (diversidade da dieta) ou das cadeias de suprimentos. Tal índice, no entanto, quando aplicado isoladamente, apresenta uma desvantagem: um alimento consumido/produzido em quantidade mínima é contabilizado tanto quanto um importante componente da dieta de um indivíduo ou da cadeia de suprimentos(34). Sendo assim, outros indicadores comumente empregados na área de economia e ecologia (Ex.: Índice de Simpson e de Shannon) passaram a ser utilizados na investigação da biodiversidade alimentar com intuito de levar em conta não apenas o número das espécies consumidas, mas a distribuição entre elas(34). Essas métricas, porém, são geralmente aplicadas em dados de disponibilidade nacional de alimentos (Ex.: Folhas de balanço publicados pela Organização das Nações Unidas para a Alimentação e a Agricultura - FAO)(43-45) ou dados de consumo de diferentes grupos alimentares(46). Apenas um estudo conduzido por Lachat et al.(28) investigou a relação entre a riqueza (métrica: Riqueza de espécies) e a distribuição de espécies (métricas: Índice de Simpson e Diversidade funcional) vegetais e animais consumidas por indivíduos residentes em áreas rurais de sete países de baixa e média-renda (n=6.226) e a adequação de micronutrientes. Ao que se sabe, nenhum estudo buscou identificar quais características do consumo alimentar influenciam, favorável ou desfavoravelmente (no que diz respeito ao número de espécies demandadas pela alimentação), a agrobiodiversidade.

A presente tese teve como objetivo preencher essa lacuna na literatura nacional e internacional, uma vez que introduz uma abordagem metodológica capaz de estimar a agrobiodiversidade da dieta, bem como investiga a diversidade de espécies vegetais mobilizadas por aquisições de alimentos no Brasil por meio da aplicação de uma métrica que leva em conta não apenas o número de espécies demandadas, mas também a igualdade de distribuição das espécies na amostra.

1.4. REFERÊNCIAS

1. FAO. The State of the World's Biodiversity for Food and Agriculture. Rome: FAO Commission on Genetic Resources for Food and Agriculture Assessments, 2019.
2. FAO. Sustainable diets and biodiversity: directions and solutions for policy, research and action. Rome FAO Nutrition and Consumer Protection Division, 2010.
3. Bioversity International. Mainstreaming Agrobiodiversity in Sustainable Food Systems: Scientific Foundations for an Agrobiodiversity Index. Rome: Bioversity International, 2017.
4. Rist S, Bonanomi EB, Giger M, Hett C, Scharrer B, Jacobi J, et al. Variety is the source of life: Agrobiodiversity benefits, challenges, and needs. 2020.
5. Verger EO, Le Port A. Dietary Diversity Indicators and Their Associations with Dietary Adequacy and Health Outcomes: A Systematic Scoping Review. 2021;12(5):1659-72.
6. FAO and WHO. Sustainable healthy diets - Guiding principles. Rome: 2019.
7. Brasil. Guia alimentar para a população brasileira. In: Básica MdSSdAàSDdA, editor. 2 ed. ed. Brasília: Ministério da Saúde; 2014.
8. Allen T, Prosperi P, Cogill B, Flichman G. Agricultural biodiversity, social-ecological systems and sustainable diets. Proceedings of the Nutrition Society. 2014;73(4):498-508.
9. Antonelli A, Fry C, Smith RJ, Simmonds MSJ, Kersey PJ, Pritchard HW, et al. State of the World's Plants and Fungi 2020. Research report. Royal Botanic Gardens, Kew, 2020 2020-07-30. Report No.
10. Khoury CK, Bjorkman AD, Dempewolf H, Ramirez-Villegas J, Guarino L, Jarvis A, et al. Increasing homogeneity in global food supplies and the implications for food security. Proceedings of the National Academy of Sciences of the United States of America. 2014;111(11):4001-6.
11. HLPE. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and
Nutrition of the Committee on World Food Security. Rome: FAO, 2017.
12. Pingali P. Agricultural policy and nutrition outcomes – getting beyond the preoccupation with staple grains. Food Secur. 2015;7(3):583-91.
13. Leite FHM, Khandpur N, Andrade GC, Anastasiou K, Baker P, Lawrence M, et al. Ultra-processed foods should be central to global food systems dialogue and action on biodiversity. BMJ Global Health. 2022;7(3):e008269.
14. Mattas K, Raptou E, Alayidi A, Yener G, Baourakis G. Assessing the Interlinkage between Biodiversity and Diet through the Mediterranean Diet Case. Advances in nutrition (Bethesda, Md). 2023;14(3):570-82.
15. Monteiro CA, Cannon G, Levy RB, Moubarac J, Louzada MLC, Rauber F, et al. Ultra-processed foods: what they are and how to identify them. Public Health Nutr. 2019;22(5):936-41.
16. Fardet A, Rock E. Ultra-Processed Foods and Food System Sustainability: What are the Links? Sustainability. 2020;12(6280):1-26.
17. Anastasiou K, Baker P, Hadjikakou M, Hendrie GA, Lawrence M. A conceptual framework for understanding the environmental impacts of ultra-processed foods and implications for sustainable food systems. J Clean Prod. 2022;368:16.
18. Baker P, Machado P, Santos T, Sievert K, Backholer K. Ultra-processed foods and the nutrition transition: Global, regional and national trends, food systems transformations and political economy drivers. 2020;21(12):e13126.
19. Levy RB, Andrade GC. Three decades of household food availability according to NOVA - Brazil, 1987-2018. 2022;56:75.
20. Fanzo J, Miachon L. Harnessing the connectivity of climate change, food systems and diets: Taking action to improve human and planetary health*. Anthropocene. 2023;42:20.
21. Herrero M, Mason-D'Croz D, Thornton PK, Fanzo J, Rushton J, Godde C, et al. Livestock and Sustainable Food Systems: Status, Trends, and Priority Actions. In: von Braun J, Afsana K, Fresco LO, Hassan MHA, editors. Science and Innovations for Food Systems Transformation. Cham: Springer International Publishing; 2023. p. 375-99.

22. Fortes MF, Leite FHM, Garzillo JMF, Monteiro CA. Analysis of the Impact of the Meat Supply Chain on the Brazilian Agri-Food System. SSRN. 2020.
23. Krug AS, E BMD, Van Tassel DL, Warschefsky EJ. The next era of crop domestication starts now. Proceedings of the National Academy of Sciences of the United States of America. 2023;120(14):e2205769120.
24. Lartey A, Meerman J, Wijesinha-Bettoni R. Why Food System Transformation Is Essential and How Nutrition Scientists Can Contribute. Annals of Nutrition and Metabolism. 2018;72(3):193-201.
25. Anastasiou K, Baker P, Hendrie GA, Hadjikakou M, Boylan S, Chaudhary A, et al. Conceptualising the drivers of ultra-processed food production and consumption and their environmental impacts: A group model-building exercise. Global Food Secur. 2023;37:100688.
26. Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, et al. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. Lancet. 2019;393(10170):447-92.
27. Lane MM, Davis JA, Beattie S, Gómez-Donoso C, Loughman A, O'Neil A, et al. Ultraprocessed food and chronic noncommunicable diseases: A systematic review and meta-analysis of 43 observational studies. Obesity reviews : an official journal of the International Association for the Study of Obesity. 2021;22(3):e13146.
28. Lachat C, Raneri JE, Smith KW, Kolsteren P, Van Damme P, Verzelen K, et al. Dietary species richness as a measure of food biodiversity and nutritional quality of diets. Proceedings of the National Academy of Sciences of the United States of America. 2018;115(1):127-32.
29. Hanley-Cook GT, Huybrechts I, Biessy C, Remans R, Kennedy G, Deschasaux-Tanguy M, et al. Food biodiversity and total and cause-specific mortality in 9 European countries: An analysis of a prospective cohort study. PLos Med. 2021;18(10):23.
30. Vogliano C, Raneri JE, Coad J, Tutua S, Wham C, Lachat C, et al. Dietary agrobiodiversity for improved nutrition and health outcomes within a transitioning indigenous Solomon Island food system. Food Secur. 2021;13(4):819-47.
31. da Silva MAL, Rodrigues LB, Domene SMA, Louzada MLD. Household availability of foods from Brazilian biodiversity. Cad Saude Publica. 2023;39(6):11.
32. Gomes SM, Chaves VM, de Carvalho AM, da Silva EB, Neto EJD, Moura GD, et al. Biodiversity is overlooked in the diets of different social groups in Brazil. Scientific Reports. 2023;13(1):10.
33. Convention on Biological Diversity. Kunming-Montreal Global Biodiversity Framework. Montreal, Canada: 2022.
34. Hanley-Cook GT, Daly AJ. Food biodiversity: Quantifying the unquantifiable in human diets. 2023;63(25):7837-51.
35. Blundo-Canto G, Cruz-Garcia GS, Talsma EF, Francesconi W, Labarta R, Sanchez-Choy J, et al. Changes in food access by mestizo communities associated with deforestation and agrobiodiversity loss in Ucayali, Peruvian Amazon. Food Secur. 2020;12(3):637-58.
36. Boedecker J, Odour FO, Lachat C, Van Damme P, Kennedy G, Termote C. Participatory farm diversification and nutrition education increase dietary diversity in Western Kenya. Matern Child Nutr. 2019;15(3):12.
37. Castaneda-Navarrete J. Homegarden diversity and food security in southern Mexico. Food Secur. 2021;13(3):669-83.
38. Ekesa B, Ariong RM, Kennedy G, Baganizi M, Dolan I. Relationships between land tenure insecurity, agrobiodiversity, and dietary diversity of women of reproductive age: Evidence from Acholi and Teso subregions of Uganda. Matern Child Nutr. 2020;16(S3).
39. Kapulu N, Chomba C, Nkonde C, Holmes M, Manda S, Smith HE, et al. Dietary diversity of women from soybean and non-soybean farming households in rural Zambia. Frontiers in Sustainable Food Systems. 2023;7:15.
40. Khandoker S, Singh A, Srivastava SK. Leveraging farm production diversity for dietary diversity: evidence from national level panel data. Agric Food Econ. 2022;10(1):20.
41. Sibhatu KT, Qaim M. Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. Food Policy. 2018;77:1-18.

42. Clark M, Springmann M, Rayner M, Scarborough P, Hill J, Tilman D, et al. Estimating the environmental impacts of 57,000 food products. Proceedings of the National Academy of Sciences of the United States of America. 2022;119(33):e2120584119.
43. Remans R, Wood SA, Saha N, Anderman TL, DeFries RS. Measuring nutritional diversity of national food supplies. Global Food Secur. 2014;3(3):174-82.
44. Nelson G, Bogard J, Lividini K, Arsenault J, Riley M, Sulser TB, et al. Income growth and climate change effects on global nutrition security to mid-century. Nature Sustainability. 2018;1(12):773-81.
45. Chaudhary A, Gustafson D, Mathys A. Multi-indicator sustainability assessment of global food systems. Nature Communications. 2018;9.
46. Tian X, Wu M, Zang J, Zhu Y, Wang H. Dietary diversity and adiposity in Chinese men and women: an analysis of four waves of cross-sectional survey data. European Journal of Clinical Nutrition. 2017;71(4):506-11.

2. OBJETIVOS

2.1. OBJETIVO GERAL

Estudar a agrobiodiversidade mobilizada pela aquisição domiciliar de alimentos no Brasil e a influência que padrões dessa aquisição exercem sobre a agrobiodiversidade.

2.2. OBJETIVOS SPECÍFICOS

- Desenvolver uma abordagem metodológica capaz de estimar a agrobiodiversidade mobilizada pela aquisição domiciliar de alimentos.

- Descrever a agrobiodiversidade mobilizada pela aquisição domiciliar de alimentos no Brasil em 2017-18.

- Analisar a influência que a participação de alimentos ultraprocessados e a participação da carne bovina exercem sobre agrobiodiversidade mobilizada pela aquisição domiciliar de alimentos.

3. RELAÇÃO ENTRE OS MANUSCRITOS DA TESE

O primeiro manuscrito da tese " *Ultra-processed foods should be central to global food systems dialogue and action on biodiversity*" (em inglês), foi elaborado em 2021, em paralelo aos principais eventos globais que aconteciam naquele ano, incluindo a Primeira Cúpula de Sistemas Alimentares da ONU, a Conferência de Biodiversidade da ONU (COP15) e a Conferência das Nações Unidas sobre Mudança Climática (COP26). A nossa principal motivação foi lançar luz sobre a contribuição das dietas globais caracterizadas por uma elevada ingestão de alimentos ultraprocessados para a perda de agrobiodiversidade e destacar a completa ausência de tais discussões nas agendas globais de sistemas alimentares, convenções de biodiversidade e conferências sobre alterações climáticas. Além de introduzir parte das hipóteses desta tese, este comentário também apresentou resultados preliminares dos manuscritos subsequentes.

O segundo manuscrito da tese "*Methodology for determining the agrobiodiversity that underlies human diets: an application using Brazilian food purchase data* " (em inglês) foi elaborado na sequência, com o propósito de responder ao primeiro objetivo específico desta pesquisa, por meio da apresentação da abordagem metodológica desenvolvida com a finalidade de determinar a agrobiodiversidade demandada pela dieta humana, e aplicação dessa abordagem em dados de aquisição domiciliar de alimentos no Brasil. Ao que se sabe, este é o primeiro estudo elaborado com tal objetivo no Brasil e, potencialmente, também na literatura internacional.

Por fim, o terceiro e último manuscrito da tese " *Diversity of plant species mobilized by household food acquisitions in Brazil (2017-18): influence of the purchase share of beef and ultra-processed foods*" (em inglês) foi elaborado com o propósito de responder aos dois últimos objetivos específicos da tese. A partir da aplicação da metodologia descrita no segundo manuscrito, estimou-se a diversidade de espécies vegetais mobilizadas pela aquisição domiciliar de alimentos no Brasil (2017-18) e investigaram-se os efeitos de diferentes padrões de aquisição de alimentos ultraprocessados e da carne bovina sobre a diversidade de espécies vegetais mobilizadas. Os achados deste artigo confirmaram resultados preliminares apresentados no manuscrito 1.

4. OS ALIMENTOS ULTRAPROCESSADOS DEVEM SER CENTRAIS NOS DIÁLOGOS DO SISTEMA ALIMENTAR GLOBAL E AÇÕES PARA A BIODIVERSIDADE

Este capítulo apresenta o manuscrito "*Ultra-processed foods should be central to global food systems dialogue and action on biodiversity*", de autoria de Fernanda Helena Marrocos Leite, Neha Khandpur, Giovanna Calixto Andrade, Kim Anastasiou, Phillip Baker, Mark Lawrence, e Carlos Augusto Monteiro. O artigo foi publicado na revista *BMJ Global Health* em 28 de março de 2022 (comprovante em anexo).

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Ultra-processed foods should be central to global food systems dialogue and action on biodiversity

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SUMMARY BOX

- The global industrial food system and consequent rapid rise of ultra-processed foods is severely impairing biodiversity. Yet although the impacts of existing land use and food production practices on biodiversity have received much attention, the role of ultra-processed foods have been largely ignored.
- An increasingly prominent 'globalised diet', characterised by an abundance of branded ultra-processed food products made and distributed on an industrial scale, comes at the expense of the cultivation, manufacture and consumption of traditional foods, cuisines and diets, comprising mostly fresh and minimally-processed foods.
- Ultra-processed foods are typically manufactured using ingredients extracted from a handful of high-yielding plant species, including maize, wheat, soy and oil seed crops. Animal-sourced ingredients used in many ultra-processed foods are often derived from confined animals fed on the same crops.
- The contribution of ultra-processed foods to agrobiodiversity loss are significant, but so far have been overlooked in global food systems summits, biodiversity conventions and climate change conferences. Ultra-processed foods need to be given urgent and high priority in the agendas of such meetings, and policies and action agreed.

4.1 INTRODUCTION

The worldwide spread of a 'globalised diet' characterised by an abundance of branded ultra-processed foods, has, in many countries, come at the expense of the cultivation, manufacture, retail, and consumption of fresh and minimally processed foods that comprise traditional diets. Supermarket shelves are often packed with highly advertised ultra-processed products that are made from commodity ingredients derived from a handful of high-yielding crops (e.g. glucose syrup, gluten and soy protein extracted from maize, wheat and soy, respectively)[1-3]. These products already account for more than half of the energy intake in the US and in the UK; more than a third of the energy intake in Australia and France and are rising rapidly in lower-income countries within Asia, Africa and Latin America[4 5]. Some subsections of populations have moved towards vegetarianism or veganism, but dietary patterns overall are now becoming higher in animal-sourced foods, usually from industrial production systems that use animal feed inputs from the same crops. This commentary highlights the impact of global diets characterised by a high intake of ultra-processed foods on agrobiodiversity. It calls for prioritising and addressing ultra-processed foods in global food system dialogues and policy, and country-level action.

4.2. AGROBIODIVERSITY IS UNDER SEVERE THREAT

Agrobiodiversity is "the variety and variability of animals, plants and microorganisms that are used directly or indirectly for food and agriculture"[6], and is crucial for resilient and sustainable food systems. Agrobiodiversity comprises the diversity of genetic resources and species used for food, fodder, fuel, and pharmaceuticals. It includes the diversity of non-harvested species that support food production, and those in the wider environment that support and diversify agroecosystems[6].

Global agrobiodiversity is declining, especially the genetic diversity of plants used for human consumption. More than 7,000 edible plant species have been identified and used for human food since the origin of agriculture[7], but fewer than 200 species had significant production in 2014, and only 9 crop plants accounted for more than 66% of all crop production by weight[8]. A total of 90% of humanity's energy intake comes from just 15 crop plants, and more than four billion people rely on just three of them: rice, wheat and maize[9]. Such decline in biological diversity in food systems[10], disrupts and damages biospheric processes and ecosystems that support reliable and sustainable food production, decreases diet diversity, and poses a barrier to healthy, resilient and sustainable food systems.

4.3. THE GLOBAL RISE OF ULTRA-PROCESSED FOODS IS DAMAGING AGROBIODIVERSITY

Ultra-processed foods are ready-to-eat or heat formulations made by assembling food substances, mostly commodity ingredients, and "cosmetic" additives through a series of industrial processing[11]. They include many products, such as sweetened or salty snacks, soft drinks, instant noodles, reconstituted meat products, pre-prepared pizza and pasta dishes, packaged breads, biscuits and confectionery[11]. Such products are the mainstay of a 'globalised diet' and are becoming dominant in the global food supply, with sales and consumption growing in all regions and in practically all countries, now most rapidly in upper-middle- and lower-middle-income countries[5]. This means that dietary patterns worldwide are becoming increasingly more processed and less diverse. This transition has been mainly driven by the industrialisation of food systems, technological change and globalisation, including the expansion and growing market and political power of transnational food and beverage corporations, and their global sourcing and production networks[5]. Developments in the retail sector have also contributed to growing and diversifying ultra-processed food markets, particularly in lower- and middle-income settings[5].

Displacement of traditional dietary patterns based on a rich variety of fresh and minimally processed foods and freshly prepared meals by ultra-processed foods, is undermining the diversity of edible plant species available for human food. Ultra-processed foods are manufactured with ingredients obtained from just a few high-yielding plant species[3]. An ongoing study of 7,020 ultra-processed foods sold in the main Brazilian supermarket chains has found that their 5 main ingredients included food substances derived from sugar cane (52.4%), milk (29.2%), wheat (27.7%), corn (10.7%), and soy (8.3%) (unpublished data). In Australia, the top ingredients in the 2019 packaged food and drink supply (24,229 products, mostly ultra-processed), included sugar (40.7%), wheat flour (15.6%), vegetable oil (12.8%) and milk

(11.0%)[12]. Subsequently diets are less diverse, with ultra-processed foods displacing the variety of wholefoods necessary for a balanced and healthy diet.

The homogeneity of agricultural landscapes linked with the intensive use of cheap standardised ingredients is negatively impacting cultivation and consumption of long established plant food sources, including rich varieties of grains, pulses, fruits, vegetables, and other whole foods, commonly produced by agrobiodiverse production systems[10]. Some commodities used in ultra-processed food production, such as cocoa and some vegetable oils, have particularly high per kg species extinction rates[13]. Ultra-processed food production also uses large quantities of land, water, energy, herbicides and fertilisers; and causes eutrophication and environmental degradation from greenhouse gas emissions and accumulation of packaging waste[14]. As well as species loss, all this is liable to cause ecosystem collapse, further impacting biodiversity.

Ultra-processed reconstituted meat products, such as hot dogs and chicken nuggets, cause additional agriculture biodiversity loss. Such ingredients of animal origin usually come from confined animals (mostly from a small number of livestock breeds)[10] fed on concentrates largely made with ingredients from the same few high-yielding crops used in the manufacture of plant-based ultra-processed foods. A study of the Brazilian agri-food system has found that the production of beef uses pasture and feedlot rations from just six plant varieties: *brachiaria* (the most prevalent forage plant), corn, soybean, cotton, sorghum and wheat[15]. Feedlot rations for US beef production rely on just five plant species (maize, sorghum, barley, oats, and wheat)[16]. The high demand for pastureland and for monocultures required in the production of animal-sourced foods directly impacts the production of other plant varieties. In Brazil, for example, staple food crops such as rice and beans have had their production areas reduced by around 43% and 30%, respectively, between 2008 and 2019. The area for soy production, largely used in livestock feed and as an ingredient in ultra-processed foods, increased by 69.9% in the same period[17].

The effect of ultra-processed diets on agricultural biodiversity urgently warrants further research. Preliminary findings from an ongoing study conducted with data from the Brazilian Household Budget Survey (2017-18) to investigate the impacts of different patterns of food acquisition on the diversity of plant species mobilized in their production, show that household food baskets with higher content of ultra-processed foods were associated with significantly poorer agricultural biodiversity (Shannon index, which reflects the diversity of species, decreasing by 13.8% from the 1st to the 5th quintile) (unpublished data).

4.4. THE NEED TO REFOCUS GLOBAL AGENDAS

Food policy dialogue and action must pay greater attention to the agrobiodiversity destruction caused by the global industrial food system. A study based on the Intergovernmental Panel on Climate Change's special Emissions Scenarios report shows that even if ecological values become more valued by and relevant to citizens and policymakers, production and consumption of food including animal products will continue to increase[18]. At present, industrial food systems that drive increased access to, and consumption of, ultra-processed foods will continue using more land, making it increasingly impossible to use land for crops that enable healthy and sustainable dietary patterns.

The unprecedented rates of biodiversity loss highlight the need for a rapid transition to dietary patterns that are rich in varieties of plant-sourced, fresh and minimally processed foods. Although the Food and Agriculture Organization and World Health Organization have been emphasising the effect of dietary patterns on human health and on ecosystems, little has been done to safeguard the health of people, animals and the environment, all together.

The calamitous effects of ultra-processed foods on human health are well documented [4 19]. However, awareness of their disastrous impact on human and planetary health remains low, and ultra-processed foods are subsequently missing from international development agendas. In the Zero draft of the United Nations Biodiversity Conference 2021[20], ultra-processed foods are not once mentioned, and there is not even any reference to the impact of the global industrial food system on biodiversity loss. Instead, a focus is on preserving and increasing consumption of wild species, and not on reducing production and consumption of foods that overall damage biodiversity.

Similarly, the UN Food Systems Summit Action Track 2 (Shifting to Sustainable Consumption)[21] and the subsequent solutions and coalitions (e.g. Healthy Diets from Sustainable Food Systems for Children and all Coalition)[22] identify animal-sourced foods, and foods high in fat, salt, sugar, as issues of concern, but make little reference to food processing, and say nothing about ultra-processed foods or its environmental impact. Although it is important that current global agendas consider the environmental impacts of food/animal production, caution is needed to avoid diverting attention away from the significant environmental impacts of other components of food supply chains[23]. In particular, the adverse impacts of ultra-processed foods on agrobiodiversity and broader environmental sustainability are nascent areas of research that need to be nurtured, not inadvertently 'squeezed out' from research and policy agendas.

4.5. CONCLUSION

The very rapid rise of ultra-processed foods in human diets will continue to place pressure on the diversity of plant species available for human consumption. Future global food systems fora, biodiversity conventions and climate change conferences need to highlight the destruction of agrobiodiversity caused by ultra-processed foods, and to agree on policies and actions designed to slow and reverse this disaster. Relevant policymakers at all levels, researchers, professional and civil society organisations, and citizen action groups, need to be part of this process.

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4.6. REFERENCES

1. Leite FHM, de Carvalho Cremm E, de Abreu DSC, et al. Association of neighbourhood food availability with the consumption of processed and ultra-processed food products by children in a city of Brazil: a multilevel analysis. Public Health Nutrition 2018;**21**(1):189-200 doi: 10.1017/S136898001600361X[published Online First: Epub Date]|.
2. Borges CA, Gabe KT, Jaime PC. Consumer Food Environment Healthiness Score: Development, Validation, and Testing between Different Types of Food Retailers. International Journal of Environmental Research and Public Health 2021;**18**(7) doi: 10.3390/ijerph18073690[published Online First: Epub Date]|.
3. Fardet A, Rock E. Ultra-Processed Foods and Food System Sustainability: What are the Links? Sustainability 2020;**12**(6280):1-26 doi: 10.3390/su12156280[published Online First: Epub Date]|.
4. Monteiro CA, Lawrence M, Millett C, et al. The need to reshape global food processing: a call to the United Nations Food Systems Summit. BMJ global health 2021;**6**(7) doi: 10.1136/bmjgh-2021-006885[published Online First: Epub Date]|.
5. Baker P, Machado P, Santos T, et al. Ultra-processed foods and the nutrition transition: Global, regional and national trends, food systems transformations and political economy drivers. Obesity reviews : an official journal of the International Association for the Study of Obesity 2020 doi: 10.1111/obr.13126[published Online First: Epub Date]|.
6. Food and Agriculture Organization of the United Nations (FAO). What is Agrobiodiversity? Secondary What is Agrobiodiversity? 1999. http://www.fao.org/3/y5609e/y5609e01.htm.
7. Antonelli A, Fry C, Smith RJ, et al. State of the World's Plants and Fungi 2020, 2020.
8. Food and Agriculture Organization. The State of the World's Biodiversity for Food and Agriculture. In: Pilling JBD, ed. FAO Commission on Genetic Resources for Food and Agriculture Assessments Rome. Rome: FAO, 2019:572.
9. Food and Agriculture Organization of the United Nations (FAO). The Commission on Genetic Resources for Food and Agriculture (CGRFA) Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture (PGRFA). Rome, Italy: FAO, 2012.
10. Rist S, Bonanomi EB, Giger M, et al. Variety is the source of life: Agrobiodiversity benefits, challenges, and needs. Swiss: Swiss Academy of Sciences (SCNAT) 2020.
11. Monteiro CA, Cannon G, Levy RB, et al. Ultra-processed foods: what they are and how to identify them. Public Health Nutrition 2019;**22**(5):936-41 doi: 10.1017/S1368980018003762[published Online First: Epub Date]|.
12. Gaines A, Shahid M, Huang L, et al. Deconstructing the Supermarket: Systematic Ingredient Disaggregation and the Association between Ingredient Usage and Product Health Indicators for 24,229 Australian Foods and Beverages. Nutrients 2021;**13**(6) doi: 10.3390/nu13061882[published Online First: Epub Date]|.
13. Moberg E, Potter HK, Wood A, et al. Benchmarking the Swedish diet relative to global and national environmental targets-Identification of indicator limitations and data gaps. Sustainability 2020;**12**(4) doi: 10.3390/su12041407[published Online First: Epub Date]|.
14. Anastasiou K, Baker P, Hadjikakou M, et al. A review of the environmental impacts of ultra-processed foods: what are the implications for sustainable food systems? [under review].
15. Fortes MF, Leite FHM, Garzillo JMF, et al. Analysis of the impact of the meat supply chain on the Brazilian agri-food system. SSRN preprint 2021
16. Eshel G, Shepon A, Makov T, et al. Partitioning United States' feed consumption among livestock categories for improved environmental cost assessments. The Journal of Agricultural Science 2015;**153**(3): 432 - 45 doi: https://doi.org/10.1017/S0021859614000690[published Online First: Epub Date]|.
17. CONAB. Portal de informações agropecuárias (Agricultural informaion). Companhia Nacional de Abastecimento (National Supply Company). In: CONAB, ed. Brasilia, 2020.
18. Bodirsky BL, Rolinski S, Biewald A, et al. Global Food Demand Scenarios for the 21st Century. PLoS ONE 2015;**10**(11):e0139201 doi: 10.1371/journal.pone.0139201[published Online First: Epub Date]|.

19. Monteiro CA, Cannon G, Lawrence M, et al. Ultra-processed foods, diet quality, and health using the NOVA classification system. Rome: Food and Agriculture Organization, 2019.
20. Convention on Biological Diversity. Recommendation adopted by the open-ended working group on the post 2020 Global Biodiversity framework. . Rome, 2020.
21. United Nations. Action Track 2 – Shift to healthy and sustainable consumption patterns, United Nations Food Systems Summit 2021. Action Track Discussion Starter: United Nations, 2021.
22. United Nations Food Systems Summit. The Coalition of Action for Healthy Diets from Sustainable Food Systems for Children & All 2021.
23. Crippa M, Solazzo E, Guizzardi D, et al. Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food 2021;**2**(3):198-209 doi: 10.1038/s43016-021-00225-9[published Online First: Epub Date]|.

5. METODOLOGIA PARA DETERMINAÇÃO DA AGROBIODIVERSIDADE SUBJACENTE À DIETA HUMANA: UMA APLICAÇÃO UTILIZANDO DADOS BRASILEIROS DE AQUISIÇÃO DOMICILIAR DE ALIMENTOS

Este capítulo apresenta o manuscrito "Methodology for determining the agrobiodiversity that underlies human diets: an application using Brazilian food purchase data", de autoria de Fernanda Helena Marrocos Leite, Giovanna Calixto Andrade, Eurídice Martínez Steele, Josefa Maria Fellegger Garzillo, Renata Bertazzi Levy, Jessica Fanzo, Carlos Augusto Monteiro, e Neha Khandpur. O artigo foi submetido para publicação na revista *BMJ Global Health* (comprovante em anexo).

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Methodology for determining the agrobiodiversity that underlies human diets: an application using Brazilian food purchase data

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Competing interests declaration

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ABSTRACT

Introduction: Measuring the agrobiodiversity linked to human diets is an important first step to generate evidence on the effects of different dietary patterns on the diversity of cultivated crops, livestock, wild animals/plants, and other forest products used for food. This study aimed to describe a methodological approach for determining the agrobiodiversity that underlies human diets; and to apply that approach to Brazilian food purchase data.

Methods: A sequential, four-step approach was developed to determine the agrobiodiversity linked to human diets, including: 1) Identifying fit-for-purpose dietary data and compiling a food list, 2) Disaggregating multi-ingredient items into individual ingredients, 3) Disaggregating single-ingredient animal-based foods into the plants and/or animals used as feed, and 4) Combining species-level data with dietary data. These steps were applied to Brazilian household food purchase data (2017-18) to estimate the diversity of plant species underlying household food acquisitions (in kg-person-year).

Results: A total 225 plant species were identified. *Brachiaria*, the most prevalent forage used as pasture in livestock production, represented more than 80% of the total amount of plant species (kg-person-year) mobilised through purchases of fresh beef meat or minimally processed dairy products, and industrially prepared multi-ingredient items with beef/dairy in their composition. This species was followed by high-yielding crops (e.g. maize, soybean, wheat, sugarcane) - mostly used as feed inputs and as ingredients of multi-ingredient items such as ultra-processed foods - and other plant species traditionally consumed such as rice, banana and beans.

Conclusion: This study presents a multi-step approach that could be adapted, replicated or extended to other contexts. Integrating methods that allow for investigation of the effects of an increasingly prominent ‘globalised diet’ on agrobiodiversity is fundamental for monitoring the status and trends of various components of agrobiodiversity.

Keywords: agrobiodiversity, agricultural biodiversity, diets, food purchase, multi-step approach, Brazil

SUMMARY BOX

What is already known on this topic

- Agrobiodiversity is key for meeting food and nutrition needs, while reducing negative effects on the environment and generating multiple ecosystems services. Yet the biological diversity of both wild and cultivated species used for human food has been declining at unprecedented rates globally.
- There is a lack of methodological approach to determine the agrobiodiversity linked to human diets.

What this study adds

- This study provides a blueprint for determining the agrobiodiversity underlying human diets by considering not only the diversity of species directly consumed (including ingredients of multi-ingredient items), but also the diversity of species required as pasture and feed inputs in the production of farmed animals.
- Our methodology can be replicated in different contexts and comparable, and provides an insight into key dimensions of dietary patterns that can be protective of or detrimental to agrobiodiversity.

How this study might affect research, practice or policy

- The Food and Agriculture Organization’s report on the State of the World's Biodiversity for Food and Agriculture 2019 highlights the urgent need to establish new metrics and systems for monitoring biodiversity, including agrobiodiversity.
- Measuring the agrobiodiversity linked to human diets is an important first step to generate evidence on the effects of different dietary patterns on agrobiodiversity.
- Evidence generated through the use of this methodology has the potential to influence international dialogue, policies and actions on agrobiodiversity conservation/restoration

5.1 INTRODUCTION

Biodiversity, broadly defined as 'the variety and variability among living organisms from all sources (both within and between species) and the ecosystems of which they are part(1), is a pre-condition for preserving natural resources and sustaining life. Agricultural biodiversity is a vital sub-set of biodiversity that encompasses the variety of animal and plant species and other organisms used directly or indirectly for food and agriculture(2, 3). Maximizing agricultural biodiversity is key for meeting food and nutrition needs, while reducing negative effects on the environment and generating multiple ecosystems services (e.g. soil erosion control, pollination, pest and disease control, wild biodiversity conservation, soil quality)(2). However, the use of agrobiodiversity is influenced by many factors, including agricultural production systems and dietary patterns, with both exerting influences on the variety of species required for food(4, 5).

Globally, the biological diversity of both wild and cultivated species has been declining at unprecedented rates(1, 6). Over the last decades, and particularly after de Green Revolution, agricultural programs and policies have focused on prioritising a small handful of highly productive livestock breeds and increasing yield of a limited number of staple foods (e.g. rice, maize and wheat) to the detriment of thousands of other edible species(1, 4). The subsequent homogenization of global food supplies and diets have been associated with all forms of malnutrition and other diet-related non-communicable diseases(7-9). At the same time, agrobiodiversity loss severely impairs food systems adaptation and resilience, and poses a risk to food and nutrition security(2). Both restoration and improved conservation of agrobiodiversity are therefore key for improving nutrition and health, facing the challenges of climate change, and achieving more sustainable and equitable production systems(1, 2).

The Food and Agriculture Organization's report on the State of the World's Biodiversity for Food and Agriculture 2019 highlights the urgent need to establish new metrics and systems for monitoring biodiversity, including agrobiodiversity, and to make the transition towards more diverse and resilient food systems(1). Measuring the agrobiodiversity linked to human diets is an important first step to generate evidence on the effects of different dietary patterns on the diversity of cultivated crops, livestock, wild animals and plants, and other forest products used for food.

Previous attempts at linking agrobiodiversity and human diets have focused primarily on two main approaches: 1) estimating the food biodiversity (or the diversity of wild and cultivated plants, animals, and other organisms directly consumed/acquired)(10-14); 2) investigating the relationship between agricultural biodiversity (e.g. diversity of plant and animal species grown/raised for food) and dietary diversity, particularly of small-holder farmers and vulnerable populations in lower-income settings(15-20). While food biodiversity has the potential to capture dietary diversity at the lowest taxonomical level (e.g. at the species levels instead of between food group) this estimate alone is not capable of investigating the agrobiodiversity effects of human diets, since it does not account for the diversity of species underlying food consumption (e.g. species required as feed inputs in the production of farmed animals)(21). For instance, dietary patterns rich in poultry vs beef meat might exert different burdens on agrobiodiversity given that both the variety and total amounts of species utilised as animal feed differ among dominant livestock categories and different production systems(22). Studies that have used the second approach also present a few limitations: 1) they have not captured variability at the species levels (since most of the studies have focused on the diversity of specific food groups, that include many species); 2) they have not taken into account the variety of species used in industrially prepared multi-ingredient items (e.g. sweet/salty biscuits, soft drinks, ready-to-eat meals); 3) they have investigated the associations between dietary diversity and agricultural diversity without evaluating the effects that different dietary patterns (based on criteria other than food group diversity) exert on agrobiodiversity. For instance, dietary patterns rich in ultra-processed foods might have different effects on agrobiodiversity than dietary patterns rich in unprocessed or minimally processed foods(23).

The present study adds to the literature by presenting a new methodological approach to determine the agrobiodiversity linked to human diets that considers not only the wild and agricultural species directly consumed or acquired (including ingredients of industrially prepared multi-ingredient items), but also captures the diversity of species used as pasture and feed inputs in the production of farmed animals. The aims of this study were to (1) describe a methodological approach for determining the agrobiodiversity that underlies human diets; and (2) apply that approach to Brazilian food purchase data.

5.2 METHODS

Describing the methodological approach

A sequential, four-step approach is followed to determine the agrobiodiversity that underlies human diets. The approach includes:

Step 1. Identifying fit-for-purpose dietary data and compiling a food list
Step 2. Disaggregating multi-ingredient items into individual ingredients
Step 3. Disaggregating single-ingredient animal-based foods into the plants and/or animals used as feed
Step 4. Combining species-level data with dietary data

Step 1. Identifying fit-for-purpose dietary data and compiling a food list

Depending on the study objective, this dietary data may be representative of the national population data (e.g. data from National Household Surveys)(13, 14) or from specific samples (from specific settings/regions)(10, 12). The level of detail of dietary information, seasonality of the dietary data collected, and the number and sequence of days (non-consecutive vs not) over which data were collected, are other factors that could differentially influence the underlying agrobiodiversity(21). Despite the difference in the specificity of dietary intake collected, both 24-hour recalls and food frequency questionnaires (FFQs), have been previously used to assess the dietary biodiversity(24). Data from household food acquisition surveys could be utilised as a proxy of food consumption(25).

The first step in working with dietary data is to compile a food list of all unique foods and beverages consumed or acquired. Subsequently, they will need to be identified as: (1) single-ingredient plant-based food or other edible fungi/algae (e.g. rice, beans, banana, mushrooms, yeast, seaweed), 2) single-ingredient animal-based food (e.g. fresh meats, eggs, milk, plain yogurt, unsalted butter), (3) multi-ingredient items (e.g.

home-made items such as roasted vegetables, cooked rice, fried chicken; industrially prepared items such as biscuits, packaged breads, ready-to-eat meals, non-alcoholic and alcoholic beverages), and (4) single-ingredient items that do not represent a species (e.g. water, salt).

Step 2. Disaggregating multi-ingredient items into individual ingredients

In Step 2, multi-ingredients items (either home-made or industrially prepared) are disaggregated into individual ingredients. For home-made items, recipe files accompanying National Survey datasets or standardised recipes from other sources could be used(26). Disaggregation of industrially prepared items can be done using standardized recipe files from the National Health Survey(27) or back-of-package ingredient information available from food labelling datasets(28).

Step 3. Disaggregating single-ingredient animal-based foods into the plants and/or animals used as feed

Single-ingredient animal-based foods are further disaggregated into the plants and/or animals used as feed in their life cycle. If the effects of animal feed systems on agricultural landscapes and global food systems is to be estimated, then animal-based foods could be disaggregated into their pasture/feed input species (e.g. soybean, wheat, maize, etc.). For this, single-ingredient animal-based items identified in the dietary data source would be further classified as: (1) terrestrial or aquatic wild animals that do not require feed inputs in their life cycle, (2) farmed animals that require feed inputs in their life cycle. Secondary data could inform this categorisation. Items classified in the first category would be included in the food list as such in this step and excluded from the analysis in step 4.

The process of identifying and estimating the total amount of animal/plant-sourced ingredients used as feed inputs in different contexts would involve: 1) estimating the total amount of feed required in the animal's life cycle by functional unit (e.g. 3.3 kg of feed in 1 kg of pork carcass), 2) identifying all the unique animal and plant-based ingredients utilised as pasture and feed inputs, 3) calculating the respective amounts of ingredients utilised as feed inputs, and 4) determining the total amount of animal/plant-based ingredients required as pasture and feed input in the production of 1kg/1litre of animal-based foods, including animal meat, animal milk, animal eggs and animal lard/offal(22). Data from life cycle inventories or from national and international animal feed reports could inform the percent composition of each animal/plant-based feed input and the total amount of plant/animal-based ingredients required in the animal life cycle/per functional unit(22). Then, conversion/correction factors should be applied to estimate the amounts of plant/animal-based ingredients required to produce 1kg of edible portion of animal-based foods (e.g. 1 kg of carcass to 1kg of bone-in or boneless meat).

At this stage, dietary data are completely disaggregated into individual ingredients.

Step 4 – Combining species-level data with dietary data

In step 4, all unique ingredients disaggregated above are classified at the species level using databases such as Catalogue of Life or regional/local databases (e.g. African Flowering Plant database, Flora and Fungi of Brazil)(10, 29). Then, acceptance of an extracted name is checked, as recommended by Nesbit et al (2010). For instance, the unique botanical name of 'wheat' is *Triticum aestivum* L. (30). Food items pertaining to the same species (e.g. maize flour, maize oil, maize grain) are all identified once (e.g. maize). At this stage, the dietary data is completely disaggregated and identifiable at the species level.

Finally, species-level food list is linked back to the individual-level dietary data in proportion to the food products acquired/consumed. Through this step, the total amount of all species underlying human diets (including those directly consumed/acquired or those that are used as pasture/feed input in the production of multi-ingredient items and animal-based foods) are estimated. If the objective of the study is to determine the diversity of plant and animal species that are linked to human diets, then items that do not represent a species (e.g. salt, water) would be flagged for exclusion at this stage. If the objective of the study is to focus exclusively on the plant species underlying human diets, then both wild/aquatic species that do not require pasture/feed input in their life cycle, or that require other ingredients that do not represent a species would also be considered for exclusion.

Data analysis

Total amounts (in kilograms/litres) and weight proportions (percentage of total species weight in kilograms/litres) of unique species linked to human diets are estimated by summing up the total amount of the respective species required through food consumption/acquisition.

The results sections detail the application of this methodology to the Brazilian context.

5.3. APPLICATION OF METHODOLOGY AND RESULTS

Step 1. Identifying fit-for-purpose dietary data and compiling a food list

The dietary data analysed in this study was collected as part of the National Household Budget Survey (HBS), conducted by the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* - IBGE) between July 2017 and July 2018(31). The 2017-18 HBS is the most recent nationally representative survey involving 57,920 Brazilian households selected using cluster sampling, in two stages: 1) random selection of census tracts; 2) random selection of households within those tracts(31). Interviews were distributed uniformly in each selected stratum (n=575) during the four quarters of the study year to capture seasonal variations in purchases.

All food items acquired by Brazilian households were identified through the 7-day food purchase record filled by participants or by interviewers (e.g. in case of illiteracy) in a collective expenditure booklet (in home measurements or acquisition units) and converted into kilograms or litres by IBGE. At the time of database creation, each registered food item received a unique code. For the present study, a food list of unique foods and beverages along with their codes was compiled. In total, 1,862 unique items were identified, of which 558 (30%) were classified as single-ingredient plant-based foods or other edible fungi/algae (e.g. apple, potato, rice, beans, mushrooms), 469 (25.2%) as single-ingredient animal-based foods (e.g. beef meat, cow’s milk, poultry, unsalted butter, plain yogurt), 816 (43.8%) as industrially prepared multi-ingredient items (e.g. packaged bread, sweet biscuits, beer, flavoured yogurt) and 19 (1%) as single-ingredient items that did not represent a species (e.g. salt, water) or excluded from our analysis (e.g. artificial sweeteners).

Step 2. Disaggregating multi-ingredient items into individual ingredients

In this step, individual ingredients of industrially prepared multi-ingredient items were identified. Since in the present study we used purchase data only, no disaggregation into recipes was needed.

Data from the Idec/Nupens/UNC food labelling database, including information from ingredient lists from packaged foods sold in the five largest supermarket chains in Brazil, were used. Approximately 13,000 products had all sides of their package photographed between April and July 2017 by fieldworkers as described by Ricardo et al.(32). Data from product labels, including the ingredient list, were entered by trained nutritionists in an online platform(32). A placeholder variable was created for each individual ingredient to indicate the location of that ingredient in the original ingredient list, presented in descending order of weight according to national food label legislation (e.g. "list1" variable indicated the first ingredient in the list, "list2" variable the second ingredient, etc.) (*Appendix 1, Supplementary Information Text).* Then, multi-ingredient items available in the food labelling database were grouped into food subgroups (n=100 food subgroups, see *Appendix 2*). Subgroups were created based on their nutritional characteristics/composition; also taking into account the species of origin (especially animal-source foods). For instance, reconstituted meats were categorized according to their level of industrial processing(33) and species of origin, as following: smoked beef; salt-cured/dried beef; canned beef; reconstituted beef; processed poultry meat; smoked pork; salt-cured/dried pork; reconstituted/canned pork; smoked fish and seafood; salt-cured/dried fish and seafood; canned fish and seafood; ultra-processed beef meat; ultra-processed pork meat; ultra-processed poultry meat; ultra-processed fish and seafood meat.

The final ingredient composition of subgroups of industrially prepared multi-ingredient items was estimated by first determining the most frequently repeated ingredient based on the disaggregated information of individual items comprising the subgroup. Then, the percentage composition of the ingredients was estimated (see Figure 1). *Appendix 1, Supplementary Information Text* has further details.

Figure 1 presents an example of the steps applied for disaggregating multi-ingredient items within the subgroup “sweet biscuits" (n= 576). The number of ingredients across different food items within this subgroup varied from 4 to 32, and the number of non-additive ingredients (excluding food additives and fortifiers) varied from 4 to 14. The final composition estimated for this subgroup was wheat flour (40%), sugar (30%), palm oil (18%), cocoa (6.5%), inverted sugar (5%), salt (0.5%) and additives. For further details on the decisions made throughout this process, see *Appendix 1 Supplementary Information Text*.

Step 3. Disaggregating single-ingredient animal-based foods into the plants and/or animals used as feed

All animal-based foods/ingredients were disaggregated into the plant species utilised as pasture or feed inputs in the production of farmed animals since the objective was to estimate the agrobiodiversity effects of the Brazilian diet.

In this step, single-ingredient animal-based foods were further categorised as (1) terrestrial or aquatic wild animals that do not require feed inputs in their life cycle (these were excluded from the analysis in step 4); (2) farmed animals that require feed inputs in their life cycle. Secondary data informed this categorisation (see *Appendix 1 Supplementary Information Text*). Farmed animal-based foods were categorized into selected reference groups (cattle, pork, broilers, chicken eggs, farmed fish/seafood, cow's milk, and dairy products), based on the frequency of consumption by the Brazilian population(31). Then plant species used in their life cycles were estimated. For cattle and dairy cows, the methodology developed by Fortes et al.(34) that is based on existing production systems in Brazil was used. This study quantified the feed requirements (kg) for beef cattle and assessed the variety and total amounts of plant species required in the production of 1 kg of beef in the national livestock panorama. For non-beef foods and selected dairy products, data from life cycle inventories were used to obtain the total amount of plant species (in kilograms) required in the animal life cycle/per functional unit. Secondary data informed the percent composition of each species utilised as pasture (e.g. grasslands) or feed inputs in the Brazilian territory. Finally, the amount of plant species required to produce 1kg/1litre of food or drink was estimated. Correction factors to estimate the amount required to produce 1kg of edible portion of animal-based foods (e.g. 1kg of bone-in vs boneless meat) were applied. See *Appendix 3, Supplementary Information Text* for further details.

Figure 2 presents the main types and total amounts of plant species mobilised in the production of animal-based foods in the Brazilian territory (assuming none imported). Overall, only seven plant species were most frequently used in feed inputs in the Brazilian territory: brachiaria (the most prevalent forage plant used as pasture in the country), maize, soybean, rice, wheat, cotton and sorghum. Boneless beef meat required a significant amount of plant species (1kg of boneless meat = 103kg of plant species, of which 97% came from a unique species) when compared to other animal-based foods. See **Table S1** (Appendix 4) for further details.

At this stage, the dietary data were completely disaggregated. All unique ingredients underlying Brazilian food purchase data were identified and a final list including the vernacular names of identified plants, animals or other organisms was compiled.

Step 4 - Combining species-level data with dietary data

Two researchers (FHML and JMFG), working independently, identified taxonomic nomenclature of all names extracted from completely disaggregated dietary data using at least one of the search resources presented in Table 1 and recorded data into an Excel spreadsheet. The two extraction sheets were compared by FHML to check for inconsistencies. Inconsistencies were discussed and a final list was obtained. Then, acceptance of extracted names was certified by JMFG using all the selected search resources (Table 1). With exception of animal species, for which data were compiled from a unique database (Catalogue of Life), if an extracted name was accepted in at least two of these resources, we treated it as final for the purposes of this study.

A total of 351 species were identified from completely disaggregated dietary data, including 225 (64.1%) plant species, 122 (34.8%) animal species and 4 (1.1%) edible organisms from the Fungi and Protista Kingdoms (e.g. seaweed, mushrooms). A list with all species underlying Brazilian food purchases data (2017-2018 HBS) is presented in Appendix 5, Table S2.

Species-level data were then combined with dietary data. The total amount of foods and beverages purchased by households (originally presented per household over seven days) were first converted into kilograms per year. Then, the datasets containing the composition of industrially prepared multi-ingredient items and the plant species used as feed inputs in the production of animal-based foods were linked to household data in proportion to the food products acquired. At this stage, the total amount of all species underlying human diets (including those directly consumed/acquired or those that are used as feed input in the production of multi-ingredient items and animal-based foods) were estimated; animal foods that did not require feed inputs in their life cycle and items or ingredients that did not represent any species (e.g. water, salt, food additives and fortifiers) were not accounted for (**Figure 3**).

Finally, total amounts of unique plant species mobilized per capita (in kg-person-year) were estimated by summing up the total amount of the respective species required by all households belonging to the same stratum, and dividing by the number of individuals belonging to the stratum. Then, the total amount (in kg-person-year) and weigh proportion (percentage of total species weight in kg-person-year) of all plant species required by each stratum was calculated by summing up the amounts of each plant species mobilized by the stratum.

Figure 4 presents the distribution (%) of the mean total amount of plant species (in kg-person-year) mobilized by Brazilian households in 2017-18 through food acquisitions. *Brachiaria*, used as feed input in the production of beef meat and other industrially prepared multi-ingredient items with meat in their formulation, represented 83.5% of the total amount of plant species (kg-person-year) mobilised by Brazilian food acquisitions (77.7% mobilised through acquisitions of single-ingredient animal-based foods such as beef meat, cow's milk, unsalted butter, yogurt; and 5.8% through industrially prepared multi-ingredient items with beef meat and other dairy products in their composition). This species was followed by high-yielding crops such as maize (5.7%), soybean (2.4%), wheat (1.3%) and sugarcane (1.2%), and other plant species traditionally consumed by the Brazilian population such as rice (1.3%), banana (0.4%) and beans (0.3%), although these species were mobilised much lower than *brachiaria*.

5.4. DISCUSSION

The study aimed to provide a blueprint for determining the agrobiodiversity linked to human diets by considering not only the diversity of wild and cultivated plant and animal species directly consumed/acquired (including the species used as ingredients in industrially prepared multi-ingredient items), but also the diversity of species required as pasture and feed inputs in the production of farmed animals. We focused specifically on the plant species linked to Brazilian household food acquisitions to create a ‘environmental footprint' that could provide some insights into the homogeneity of global food systems.

The multi-step methodology included identification of dietary data/food list, disaggregation of multi-ingredient items into individual ingredients, disaggregation of single-ingredient animal-based foods into the plants and/or animals used as feed, and combination of species-level data with dietary data. We identified the main plant species mobilised by annual food acquisitions in Brazil (2017-18), including the most prevalent forage used as pasture in the Brazilian territory (brachiaria), high-yielding crops largely used as ingredient in industrially prepared multi-ingredient items such as ultra-processed foods (e.g. maize, soybean wheat and sugarcane), and traditionally consumed plant species (e.g. rice, banana, beans, tomato). Although 225 plant species were linked to household food acquisitions in Brazil, one species (*Urochloa brizantha,* brachiaria) was responsible for more than 80% of the species mobilised (in kg-person-year) through purchase of meat/dairy products from livestock/cows fed with pasture such as fresh beef meat, minimally processed dairy products and industrially prepared multi-ingredient items with beef in their composition. This result suggests a low diversity of plant species mobilised by the Brazilian population, however, diversity indices that account for both the total number of species and the relative distribution of their abundances in the sample (e.g. the Shannon index) should be applied to specifically test this hypothesis (low diversity of mobilised species).

A previous study explored associations between dietary patterns and food plant diversity in 12 countries (6 with adherence to the Mediterranean dietary pattern and 6 which follow a Western-type diet) using data from cultivated and native food plants as a proxy for the food plant diversity in dietary patterns(35). However, the method assumed that all plant species cultivated in a geographic unit are consumed as part of a population's diets which might not necessarily be the case. Although most of the studies carried out in lower-income countries demonstrate positive (although small) associations between crop diversity and dietary diversity of small-holder farmers and vulnerable populations, this relationship has not been explored in higher-income settings(36). Furthermore, the authors focused on the variety of plant species used as 'food' and 'food additives', 'not taking into account the plant species used as 'animal food', a component that can highly affect the agrobiodiversity linked to human diets.

The sequential, four-step approach used in our study is replicable in different contexts and flexible to accommodate available resources. We opted to define the composition of food subgroups by identifying the most frequently repeated ingredient in each position of disaggregated ingredient lists of items within the same food subgroup, but, disaggregated back-of-package ingredients lists(28) or recipes files from National Health Surveys(27) could also be used to define the composition of individual multi-ingredient products. Similarly, we used data from life cycle inventories and from national and international literature to estimate the variety and total amounts of plant species used as feed inputs in Brazil, but other resources (e.g. national statistics on animal feed production) could also have been used.

Our methodology could also be applied to evaluate other aspects of human diets like the food biodiversity or the consumption of underutilised species. Two previous studies using nationally representative household food purchase data collected over seven consecutive days and dietary data collected through two non-consecutive 24-hours recalls found that only 0.7% and 1.3% of the Brazilian population, respectively were consuming biodiverse foods(13) and underutilised foods(14) (2017-18). Although further research, policies and actions to promote the consumption of underutilised species is key for preserving biodiversity – as emphasised in The Kunming-Montreal Global Biodiversity Framework (GBF) adopted during the fifteenth meeting of the Conference of the Parties (COP 15)(37) – there is an urgent need to also consider the effects of a 'globalised diet' on agrobiodiversity. Our methodology can address this gap by testing further hypothesis on the role of different dietary exposures (e.g. ultra-processed foods and animal-based foods) in driving homogeneity of food systems.

Other health and environmental outcomes could also be investigated by employing our methodological approach. For instance, the final composition of industrially-prepared multi-ingredient items (including processed and ultra-processed meats, and other ready-to-eat meals with meat in their composition) could be combined with longitudinal data to estimate the impact of fresh vs processed/ultra-processed red meat consumption on the incidence of type 2 diabetes by considering specifically the proportion of meat used in the formulation of these multi-ingredient items. Similarly, the composition of feed inputs of farmed animals could be combined with dietary data to improve both environmental impact assessments and consumers' ability to distinguish among animal-based foods(22). For instance, according to our findings, the consumption of beef requires significant higher amounts of plant species when compared to poultry. Nevertheless, although livestock raised in Brazil rely mostly on the plant species used as pastures for feed consumption, poultry requires more high yielding crops such as maize and soybean. These trade-offs might also be considered when transitioning towards diets with lower burdens to agrobiodiversity.

This study has several strengths. First, to the best of our knowledge, this is the first study to present a methodology for determining the agrobiodiversity linked to human diets. Although previous studies using data from the FAO statistical database (FAOSTAT) have reported homogeneity of global food supplies over the last decades(7, 38), these data provide a proxy for national level consumption and cannot provide a direct measurement of dietary intakes(2). Second, we use data from the most recent and nationally representative estimate of household food acquisition in Brazil to apply the developed multi-step approach and estimate the agrobiodiversity effects of Brazilian diets. Previous study has showed that data from the national food acquisition survey is a good proxy of food consumption in the Brazilian context(25). Third, it relies on information from a national food labelling dataset collected in the five largest Brazilian supermarket chains to estimate the composition and identify the main species used as ingredients in industrially prepared multi-ingredient items (such ultra-processed foods). Although previous studies have used information from this dataset to evaluate the presence of specific ingredients/additives in packaged foods and beverages(39), our study is the first to identify the main plant and animal species used as ingredients in industrially-prepared multi-ingredient items. Fourth, we estimated the main types and total amounts of species required in the production of animal-based foods by considering the main production systems in place in the Brazilian territory. This is important since different types of production systems might exert different effects on agrobiodiversity. Finally, it applies best-practices for identifying and classifying foods at the species level, which is fundamental for accurately determining the diversity of species directly consumed or underlying household food acquisitions.

The potential limitations of our methodology must also be taken into consideration by researchers who choose to use this approach for future research. First, narrowing the analyses to plant species led to a reduction in the diversity of animal species mobilised through dietary patterns. However, this decision was based on the main objective of our study (to simulate the potential 'environmental footprint' of household food acquisitions on agricultural landscapes and homogeneity of food systems). Further research could be carried out to explore both components of agrobiodiversity. Second, defining the composition of industrially-prepared multi-ingredient items at the subgroup level could have undermined the diversity of species used as ingredients in their formulation. To overcome this, we have used the most frequently repeated ingredient in each position of the disaggregated ingredient lists of individual food items classified within the same subgroup. Third, we have considered that all animal-based foods acquired by Brazilian households were produced in Brazil (no import was assumed). This was based on secondary information showing that most of animal-based foods produced in the country (especially beef, poultry and pork meats) remains in the domestic market and that import of these items is minimal(40). Finally, the fact that we used the most predominant production systems of livestock in Brazil as reference to estimate the total amount and types of plant species required as animal food might have overshadowed the diversity of forage species that can be found in native pastures such as in the Pampa biome(41), located in the southernmost state of Brazil. Nevertheless, natural pastures represent a small portion of the soils in which cattle farming is carried out. Further research is needed to explore the role of regenerative livestock farming in diversifying the agrobiodiversity of diets.

5.5. CONCLUSION

The present study builds on previous work to determine the agrobiodiversity linked to human diets. It details a multi-step approach which could be adapted, replicated or extended to other contexts. Integrating methods that allow for investigation of the effects of an increasingly prominent ‘globalised diet’ on agrobiodiversity is fundamental for monitoring the status and trends of various components of agrobiodiversity and promoting policies and actions to preserve and restore biodiversity.

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5.6. REFERENCES

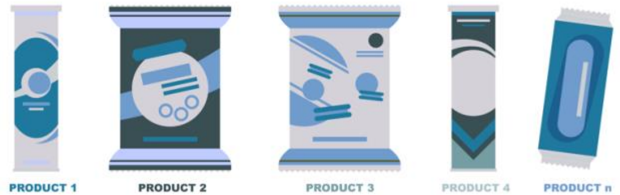
1. FAO. The State of the World’s Biodiversity for Food and Agriculture. Rome: FAO Commission on Genetic Resources for Food and Agriculture Assessments; 2019.
2. Bioversity International. Mainstreaming Agrobiodiversity in Sustainable Food Systems: Scientific Foundations for an Agrobiodiversity Index. Rome: Bioversity International; 2017.
3. FAO. Sustainable diets and biodiversity: directions and solutions for policy, research and action. Rome FAO Nutrition and Consumer Protection Division; 2010.
4. Krug AS, E BMD, Van Tassel DL, Warschefsky EJ. The next era of crop domestication starts now. Proceedings of the National Academy of Sciences of the United States of America. 2023;120(14):e2205769120.
5. Rist S, Bonanomi EB, Giger M, Hett C, Scharrer B, Jacobi J, et al. Variety is the source of life: Agrobiodiversity benefits, challenges, and needs. 2020.
6. Antonelli A, Fry C, Smith RJ, Simmonds MSJ, Kersey PJ, Pritchard HW, et al. State of the World's Plants and Fungi 2020. Research report. Royal Botanic Gardens, Kew; 2020 2020-07-30.
7. Khoury CK, Bjorkman AD, Dempewolf H, Ramirez-Villegas J, Guarino L, Jarvis A, et al. Increasing homogeneity in global food supplies and the implications for food security. Proceedings of the National Academy of Sciences of the United States of America. 2014;111(11):4001-6.
8. Pingali P. Agricultural policy and nutrition outcomes – getting beyond the preoccupation with staple grains. Food Secur. 2015;7(3):583-91.
9. HLPE. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and
Nutrition of the Committee on World Food Security. Rome: FAO; 2017.
10. Lachat C, Raneri JE, Smith KW, Kolsteren P, Van Damme P, Verzelen K, et al. Dietary species richness as a measure of food biodiversity and nutritional quality of diets. Proceedings of the National Academy of Sciences of the United States of America. 2018;115(1):127-32.
11. Hanley-Cook GT, Huybrechts I, Biessy C, Remans R, Kennedy G, Deschasaux-Tanguy M, et al. Food biodiversity and total and cause-specific mortality in 9 European countries: An analysis of a prospective cohort study. PLos Med. 2021;18(10):23.
12. Vogliano C, Raneri JE, Coad J, Tutua S, Wham C, Lachat C, et al. Dietary agrobiodiversity for improved nutrition and health outcomes within a transitioning indigenous Solomon Island food system. Food Secur. 2021;13(4):819-47.
13. da Silva MAL, Rodrigues LB, Domene SMA, Louzada MLD. Household availability of foods from Brazilian biodiversity. Cad Saude Publica. 2023;39(6):11.
14. Gomes SM, Chaves VM, de Carvalho AM, da Silva EB, Neto EJD, Moura GD, et al. Biodiversity is overlooked in the diets of different social groups in Brazil. Scientific Reports. 2023;13(1):10.
15. Blundo-Canto G, Cruz-Garcia GS, Talsma EF, Francesconi W, Labarta R, Sanchez-Choy J, et al. Changes in food access by mestizo communities associated with deforestation and agrobiodiversity loss in Ucayali, Peruvian Amazon. Food Secur. 2020;12(3):637-58.
16. Boedecker J, Odour FO, Lachat C, Van Damme P, Kennedy G, Termote C. Participatory farm diversification and nutrition education increase dietary diversity in Western Kenya. Matern Child Nutr. 2019;15(3):12.
17. Castaneda-Navarrete J. Homegarden diversity and food security in southern Mexico. Food Secur. 2021;13(3):669-83.
18. Ekesa B, Ariong RM, Kennedy G, Baganizi M, Dolan I. Relationships between land tenure insecurity, agrobiodiversity, and dietary diversity of women of reproductive age: Evidence from Acholi and Teso subregions of Uganda. Matern Child Nutr. 2020;16(S3).
19. Kapulu N, Chomba C, Nkonde C, Holmes M, Manda S, Smith HE, et al. Dietary diversity of women from soybean and non-soybean farming households in rural Zambia. Frontiers in Sustainable Food Systems. 2023;7:15.
20. Khandoker S, Singh A, Srivastava SK. Leveraging farm production diversity for dietary diversity: evidence from national level panel data. Agric Food Econ. 2022;10(1):20.

21. Hanley-Cook GT, Daly AJ. Food biodiversity: Quantifying the unquantifiable in human diets. 2023;63(25):7837-51.
22. Eshel G, Shepon A, Makov T, Milo R. Partitioning United States' feed consumption among livestock categories for improved environmental cost assessments. J Agric Sci. 2015;153(3):432-45.
23. Leite FHM, Khandpur N, Andrade GC, Anastasiou K, Baker P, Lawrence M, et al. Ultra-processed foods should be central to global food systems dialogue and action on biodiversity. BMJ Global Health. 2022;7(3):e008269.
24. de Medeiros MFA, Silva SGB, Teixeira CD, Lima S, Marchioni DM, Jacob MCM. Assessment of Biodiversity in Food Consumption Studies: A Systematic Review. Frontiers in Nutrition. 2022;9:832288.
25. Louzada MLdC, Levy RB, Martins APB, Claro RM, Steele EM, Verly Jr E, et al. Validating the usage of household food acquisition surveys to assess the consumption of ultra-processed foods: Evidence from Brazil. Food Policy. 2017;72:112-20.
26. Louzada MLC, Cruz GLD, Silva KAAN, A.G.F. G, G.C. A, F. R, et al. Consumption of ultra-processed foods in Brazil: distribution and temporal evolution 2008-2018. 2023;57:12.
27. Hendrie GA, Baird D, Ridoutt B, Hadjikakou M, Noakes M. Overconsumption of Energy and Excessive Discretionary Food Intake Inflates Dietary Greenhouse Gas Emissions in Australia. Nutrients. 2016;8(11).
28. Clark M, Springmann M, Rayner M, Scarborough P, Hill J, Tilman D, et al. Estimating the environmental impacts of 57,000 food products. Proceedings of the National Academy of Sciences of the United States of America. 2022;119(33):e2120584119.
29. The Brazil Flora Group, Gomes-da-Silva J, Filardi FLR, Barbosa MRV, Baumgratz JFA, Bicudo CEM, et al. Brazilian Flora 2020: Leveraging the power of a collaborative scientific network. TAXON. 2022;71(1):178-98.
30. Nesbitt M, McBurney RPH, Broin M, Beentje HJ. Linking biodiversity, food and nutrition: The importance of plant identification and nomenclature. J Food Compos Anal. 2010;23(6):486-98.
31. Instituto Brasileiro de Geografia e Estatística (IBGE). Pesquisa de Orçamentos Familiares 2017-2018: avaliação nutricional da disponibilidade domiciliar de alimentos no Brasil. In: IBGE, editor. Rio de Janeiro2020.
32. Ricardo CZ, Peroseni IM, Mais LA, Martins APB, Duran AC. Trans Fat Labeling Information on Brazilian Packaged Foods. Nutrients. 2019;11(9).
33. Monteiro CA, Cannon G, Levy RB, Moubarac J, Louzada MLC, Rauber F, et al. Ultra-processed foods: what they are and how to identify them. Public Health Nutr. 2019;22(5):936-41.
34. Fortes MF, Leite FHM, Garzillo JMF, Monteiro CA. Analysis of the Impact of the Meat Supply Chain on the Brazilian Agri-Food System. SSRN. 2020.
35. Mattas K, Raptou E, Alayidi A, Yener G, Baourakis G. Assessing the Interlinkage between Biodiversity and Diet through the Mediterranean Diet Case. Advances in nutrition (Bethesda, Md). 2023;14(3):570-82.
36. Sibhatu KT, Qaim M. Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. Food Policy. 2018;77:1-18.
37. Convention on Biological Diversity. Kunming-Montreal Global Biodiversity Framework. Montreal, Canada; 2022.
38. Remans R, Wood SA, Saha N, Anderman TL, DeFries RS. Measuring nutritional diversity of national food supplies. Global Food Secur. 2014;3(3):174-82.
39. Canella DS, Montera VSP, Oliveira N, Mais LA, Andrade GC, Martins APB. Food additives and PAHO's nutrient profile model as contributors' elements to the identification of ultra-processed food products. Scientific Reports. 2023;13(1):13698.
40. CONAB. Companhia Nacional de Abastecimento. AgroConab. Brasilia, DF; 2022.
41. Andrade BO, Dröse W, Aguiar CA, Aires ET, Alvares DJ, Barbieri RL, et al. 12,500+ and counting: biodiversity of the Brazilian Pampa. Frontiers of Biogeography. 2023;15(2).

5.7. TABLES AND FIGURES

Subgroup: sweet biscuits

Use back-of-package ingredient lists



I. From the disaggregated ingredient lists of food items within the subgroup, **identify the most frequently repeated ingredient** in each position (1st ingredient, 2nd ingredient, 3rd ingredient...)

II. Then, **identify known percent composition** from food labelling dataset (when listed)

III. Finally, **estimate the percent composition of remaining ingredients** using back-of-package nutritional information and other logic checks

Products	1st Ingredient	2nd Ingredient	3rd Ingredient	4th Ingredient	5th Ingredient	6th Ingredient	7th Ingredient
Product 1	wheat flour (40%)	sugar (35%)	palm oil (17%)	cocoa	inverted sugar	wholemeal flour	salt
Product 2	wheat flour	wholemeal flour	brown sugar	palm oil	vegetable oil	salt (0.49%)	additives
Product 3	sugar	wheat flour	palm oil (19%)	chocolate (sugar)	inverted sugar	starch	salt
Product 4	wheat flour	sugar (34.7%)	vegetable fat (palm) (18%)	chocolate (cocoa)	starch	salt (0.51%)	additives
Product n	fortified wheat flour	sugar (35%)	sugar	cocoa powder	sugar	salt (0.50%)	additives
Final composition	wheat flour (40%)	sugar (30%)	palm oil (18%)	cocoa (6.5%)	inverted sugar (5%)	salt (0.5%)	additives

= 100 - 40 - 30 - 18 - 5 - 0.5 = 6.5%

Added sugar = 35% (30% allocated to 'sugar' and 5% allocated to 'inverted sugar'

Figure 1. Disaggregating multi-ingredient items into individual ingredients.

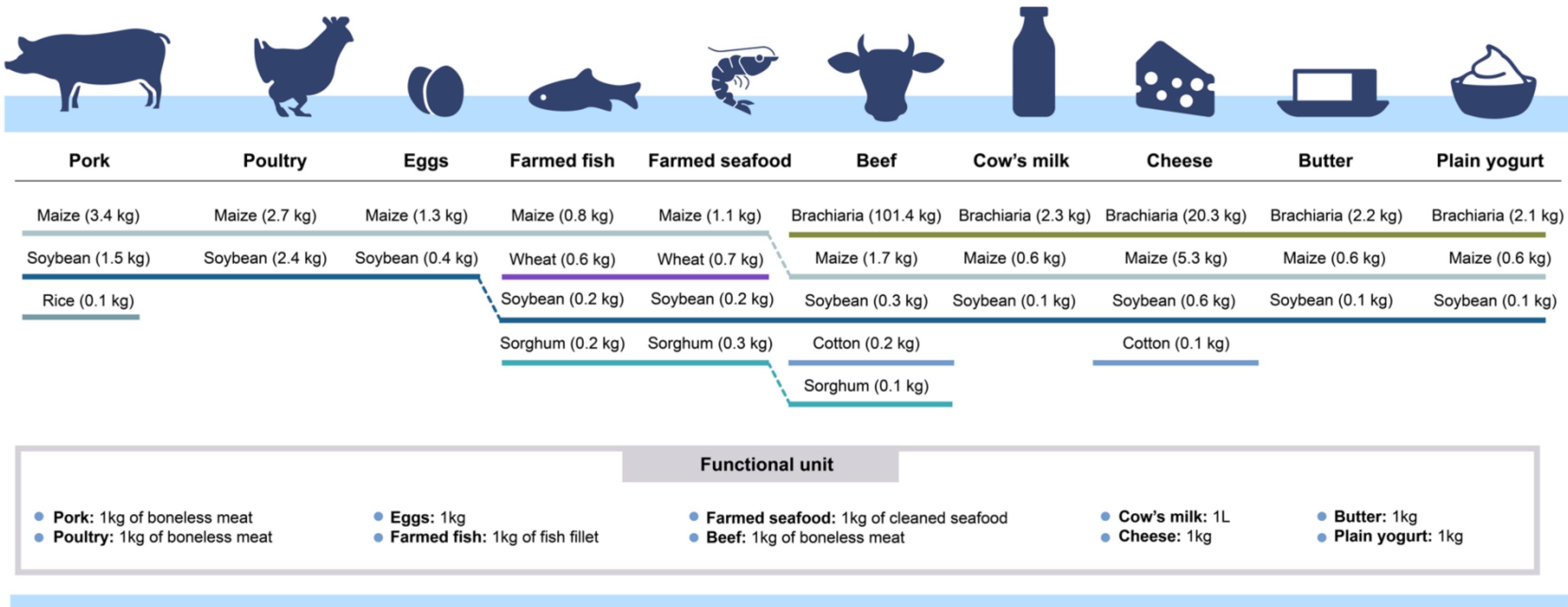


Figure 2. Main types and total amount of plant species mobilised by functional unity of animal-based foods.

Table 1. Selected data sources for identifying scientific names and checking acceptance of extracted names.

Source	Description
Scientific/accepted names	
POWO (Plants of the World Online)[a]	POWO is a global checklist of accepted plant names from the Royal Botanic Gardens, Kew. It provides the latest peer reviewed and published opinions on the accepted scientific names and synonyms of selected plant families (n=200).
WFO (The World Flora Online)[b]	WFO is an open-access, web-based compendium of the world's plant species developed by a consortium of leading botanical institutions worldwide. It presents information on 350,510 accepted plant species.
COL (Catalogue of Life)[b]	Catalogue of Life is the most comprehensive and authoritative global index of species (plants, animals, fungi and microbes) currently available. It holds essential information on the names, relationships and distributions of over 1.6 million species.
REFLORA (*Flora and Funga* of Brazil)[c]	The Brazilian Flora 2020 online system covers more than 130,000 names of species- and intraspecific-level taxa of algae, fungi, and plants.

Note: Based on [a]Nesbitt et al (2010), [b]Lachat et al (2018) and [c]The Brazil Flora Group (2022)

FOOD ITEMS	HOUSEHOLD ID	KG PER YEAR (FOOD ITEMS)	INGREDIENTS (MULTI-INGREDIENT ITEMS/ANIMAL FEED)	VERNACULAR NAME	SCIENTIFIC NOMENCLATURE	SPECIES ID	FACTOR	PLANT SPECIES (KG PER YEAR)
FIELD PUMPKIN	52003513012	12.6		FIELD PUMPKIN	*Cucurbita pepo* L.	139017	1	12.6
TABLE SUGAR	52003513012	260.7		SUGARCANE	*Saccharum officinarum* L.	101001	1	260.7
RICE	52003513012	321.4		RICE	*Oryza sativa* L.	124001	1	321.4
BANANA	52003513012	4.3		BANANA	*Musa acuminata* Colla	133046	1	4.3
BEETROOT	52003513012	5.7		BEETROOT	*Beta vulgaris* L.	138004	1	5.7
BEEF MEAT	52003513012	52.1	MAIZE	MAIZE	*Zea mays* L.	127007	1.7	88.6
BEEF MEAT	52003513012	52.1	COTTON	COTTON	*Gossypium hirsutum* L.	142002	0.19	9.9
BEEF MEAT	52003513012	52.1	WHEAT	WHEAT	*Triticum aestivum* L.	127006	0.01	0.5
BEEF MEAT	52003513012	52.1	SORGHUM	SORGHUM	*Sorghum bicolor* (L.) Moench	127005	0.09	4.7
BEEF MEAT	52003513012	52.1	SOYBEAN	SOYBEAN	*Glycine max* (L.) Merr	142006	0.33	17.2
BEEF MEAT	52003513012	52.1	BRACHIARIA	BRACHIARIA	*Urochloa brizantha* (A.Rich.) R.D.Webster	185001	101.3	5282.1
ONION	52003513012	83.0		ONION	*Allium cepa* L.	139002	1	83.0
CARROT	52003513012	18.6		CARROT	*Daucus carota* L.	139019	1	18.6
GUAVA	52003513012	7.0		GUAVA	*Psidium guajava* L.	133062	1	7.0
APPLE	52003513012	65.9		APPLE	*Malus domestica* (Suckow) Borkh.	133042	1	65.9
SOYBEAN OIL	52003513012	93.9		SOYBEAN	*Glycine max* (L.) Merr	142006	1	93.9
CHICKEN EGG	52003513012	32.5	MAIZE	MAIZE	*Zea mays* L.	127007	1.3	42.3
CHICKEN EGG	52003513012	32.5	SOYBEAN	SOYBEAN	*Glycine max* (L.) Merr	142006	0.4	13.0
~~COD~~	~~52003513012~~	~~10.0~~		~~COD~~	~~*Gadus macrocephalus* (Tilesius, 1810)~~	~~888888~~	~~1~~	~~10.0~~
TANGERINE	52003513012	12.9		TANGERINE	*Citrus reticulata* Blanco	133024	1	12.9
SALTY BISCUIT	52003513012	3.1	WHEAT FLOUR	WHEAT	*Triticum aestivum* L.	127006	0.75	2.3
SALTY BISCUIT	52003513012	3.1	PALM FAT	OIL PALM	*Elaeis guineensis* Jacq.	133028	0.15	0.5
SALTY BISCUIT	52003513012	3.1	SUGAR	SUGARCANE	*Saccharum officinarum* L.	101001	0.04	0.1
SALTY BISCUIT	52003513012	3.1	INVERTED SUGAR	MAIZE	*Zea mays* L.	127007	0.04	0.1
~~SALTY BISCUIT~~	~~52003513012~~	~~3.1~~	~~SALT~~			~~888888~~	~~0.02~~	~~0.1~~
~~SALTY BISCUIT~~	~~52003513012~~	~~3.1~~	~~BREAD IMPROVER~~			~~888888~~	~~0~~	~~0.0~~
~~SALTY BISCUIT~~	~~52003513012~~	~~3.1~~	~~FLAVORING AGENTS~~			~~888888~~	~~0~~	~~0.0~~

- SINGLE-INGREDIENT PLANT-BASED FOODS
- SINGLE-INGREDIENT ANIMAL-BASED FOODS
- INDUSTRIALLY PREPARED MULTI-INGREDIENT ITEMS

Figure 3. Combining dietary data with species-level data and estimating total amount of species mobilised by Brazilian households.

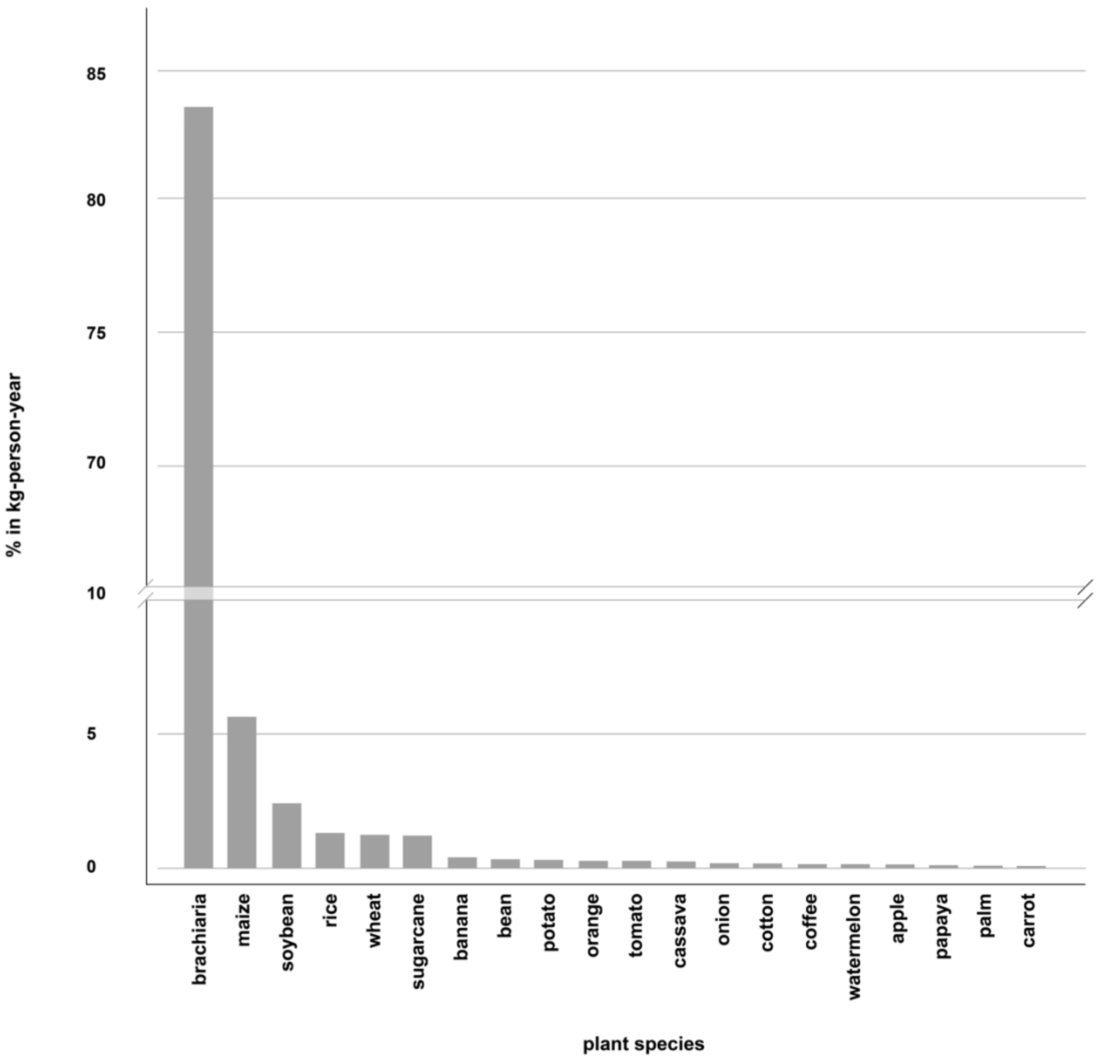


Figure 4. Distribution (%) of the mean total amount in kilograms-person-year of plant species mobilized by annual household food acquisitions (top 20 species). Brazilian household strata, July 2017-July 2018 (n=575).

5.8. SUPPLEMENTARY MATERIAL

APPENDIX 1: Supplementary Information Text: Disaggregation of industrially prepared multi-ingredient items into individual ingredients

Food labelling dataset

The data used in this analysis were collected between April and July 2017 in the five largest Brazilian supermarket chains (according to food retail annual sales data from Euromonitor 2016), as described in Ricardo et al(1). Information on name, brand, flavour, package size, nutrition facts and ingredient list of each packaged product was entered between July and November 2017 by trained nutritionists in an online platform using a template developed by researchers from the Institute of Nutrition and Food Technology (*Instituto de Nutrición y Tecnología de los Alimentos* - INTA), Chile, and the University of North Carolina at Chapel Hill (UNC), United States of America (USA).

For each data entry, the information used in the present analysis included: the product id (a code used to identify unique food items); product name; product description; product brand; ingredient list; and back of-package nutritional information (per 100g of product). We focused our analysis on multi-ingredient foods and non-alcoholic beverages. Therefore, information from packaged single-ingredient items were excluded.

Ingredient lists were provided as a single string of text for each product. Three data coders, working independently between February and April 2022, separated the ingredient lists of 8,442 multi-ingredient items. In the original dataset, individual ingredients were separated by commas, semi-colons or single spaces – placed after the percent composition for that ingredient if that information was provided (e.g. water, tomatoes 18.4%, tomato sauce 11.9%, ...). Ingredients text were separated into individual ingredients by separating the ingredients text based on the location of commas, semi-colons and single-spaces as performed by Clark et al(2). A placeholder variable was created for each individual ingredient to indicate the location of that ingredient in the original ingredient list (e.g. "list1" indicated the first ingredient in the list, "list2" the second ingredient, etc.). Embedded ingredient lists – defined as "a list of ingredients that compose a larger ingredient in a food product"(2) – were kept as a single ingredient (not separated) and the first ingredient of the list was used as the reference ingredient. For instance, if the ingredients for chocolate flavour were "chocolate flavour (sugar, starch, glucose powder, cocoa powder, vegetable oil, soy lecithin emulsifier)" then 'sugar' was selected as the reference ingredient (see Figure 1). When a compound ingredient such as "chocolate", "margarine" and "cheese" was not detailed (did not include an embedded ingredient list), similar products available in the dataset were used as reference to define the main ingredient for that item following the same methodology. Also, additional texts indicating ingredient sourcing (e.g. organically produced ingredients) and allergen information (e.g. "contain gluten") were excluded.

Then, a researcher (GCA) responsible for training the data coders and guaranteeing the quality of the process checked for inconsistencies/ potential errors in the dataset, making the necessary amendments and standardising the writing of individual ingredients. For instance, different writings for 'sugar' in Portuguese (e.g. "acucar", "açucar", "açúcar") were standardised (e.g. "açúcar") to facilitate the analysis.

Finally, multi-ingredient foods and beverages were grouped into subgroups (n=100, see Appendix 2) according to their nutritional characteristics/composition(3) (e.g. smoked or reconstituted beef, salt-cured/dried pork, breakfast cereals, baked goods and ready-to-eat meals with chicken). At this stage, it was important to differentiate the main animal species used in these products (e.g. ultra-processed fish and seafood meat; ultra-processed pork meat; ultra-processed beef meat).

Identifying most frequent ingredients and known percent composition

The following steps were undertaken to identify the most frequently repeated ingredient occupying each position of ingredient lists of products classified within the same subgroup and known percent composition (when listed):

First, the most frequently repeated ingredient occupying each position of the ingredient lists of products classified within the same subgroup were computed. For instance, if a set of lists of food items classified as "sweet biscuits" contained the following ingredients in the first position (1st ingredient) "wheat flour, wheat flour, sugar, wheat flour, fortified wheat flour, …", then the most frequently repeated ingredient would be "wheat flour", as it appears the most out of all the ingredients in that position of the ingredient lists (see Figure 1). This step was performed until a food additive/fortifier was identified amongst the ingredients that appeared most often in a certain position (at this stage, we interrupted the analysis and defined the final composition of that subgroup, using the most frequently repeated ingredient in each position of ingredient lists as criteria). Food additives and fortifiers were excluded from the analysis. This analysis was performed in Stata v. 16.1. The final composition for ingredients of each subgroup was exported and saved in an Excel file.

Second, the percent composition for ingredients of foods and non-alcoholic beverages was identified (when this information was provided). We did this by automatically exporting the ingredient lists of multi-ingredient items classified in the same subgroup from Stata to different sheets in the same Excel file (e.g. sheet1='sweet biscuits', sheet2='salty snacks', etc.). Then, we used the Excel function "conditional formatting -> highlight cells rules -> text that contains" to identify all instances that contained the percentage symbol ("%"). Afterwards, we have filtered all instances that contained the percentage symbol and saved in the aforementioned Excel file, containing the final composition for ingredients of each subgroup. Finally, we checked whether the known percent composition was provided for the same ingredient identified as the most frequent one in that location. In that case, the informed percent composition was used as reference. For instance, if the informed percent composition in the 1st position was "wheat flour (40%)" and the most frequent ingredient for that subgroup in the same position was "wheat flour", then this value (40%) was used (see Figure 1). Otherwise, that information was not utilized and other methods were applied (further details below). If more than one percent composition was informed, the most frequent percentage was selected (e.g. wheat flour 40%, wheat flour 41%, wheat flour 45%, wheat flour 40%; then 40% used).

Estimating percent composition of other most frequent ingredients

Given that only 11.4% of all multi-ingredient items available in our dataset (n=8,442) had a percent composition listed in the ingredients lists, we used a series of steps to estimate the percent composition of other most frequent ingredients for each subgroup where this information was not provided.

First, we estimated the percent composition of salt, fat and added sugar for each product available in our dataset by using back-of-package nutrition information. The estimation of added sugar was based on information of total sugars. For products without declaration of total sugars, the method proposed by Scapin et al.(4) and information from the Table of Nutritional Composition of foods consumed in Brazil(5) were used to estimate the content of added sugar. In the case of salt, the following parameter was used: 1g of salt = 400mg of sodium(6). Then, we linked this information back to the ingredient lists of each subgroup by using the 'product id' to calculate the average composition of these nutrients among all products classified in the same subgroup. The estimated percent composition was used if the most frequent ingredients of each subgroup included ingredients that were salt, fat and added sugar. If more than one most frequent ingredient contained fat or sugar in its composition (e.g. vegetable oil and cheese; sugar and glucose syrup), then the total amount of fat/sugar was divided between those ingredients by considering the order of the most frequent ingredients for that subgroup and applying other criteria as described below (e.g. linear interpolation). See an example in the Main text, Figure 1 (35% of added sugar was divided between the 3rd ingredient 'sugar' and the 5th ingredient 'inverted sugar').

Second, for ingredients where the percent composition could not be estimated using the above steps, we estimated the remaining percent composition in a series of four steps: (1) if the composition of the first most frequent ingredient was unknown and could not be estimated as detailed above, and the percent composition of the last ingredient could not be estimated using the steps above, then we assumed that the last ingredient accounted for 0.1% of the total composition to avoid overestimation, as performed by Clark et al.(2); (2) we linearly interpolated between composition values of ingredients with unknown percent composition. For instance, if the third ingredient was estimated to account for 20% and the fifth ingredient was estimated to account for 5%, then we estimated the composition of the fourth ingredient as 12.5%(2); (3) if the composition of the first n ingredients was unknown and could not be estimated as described in the above paragraphs, we used recipe files from the national dietary survey, online recipes or the percent composition of similar products to estimate their composition. For instance, we were unable to estimate the percent composition of the first three most frequent ingredients of the subgroup “pizzas” based on the steps above-mentioned so we used the recipe "mozzarella pizza” available in the national dietary survey conducted by IBGE in 2017-18 as reference to estimate the composition of those ingredients; (4) if the percent composition of a remaining ingredient could not be estimated, we assumed that this ingredient accounted for the remaining composition of the product (see Figure 1, percent composition of cocoa = 100-40-30-18-5-0.5 = 6.5%).

Finally, the percent composition of food additives identified amongst the most frequent ingredients of subgroups were not estimated as they were not included in our main analysis. Therefore, their percent composition was assumed to be 0% of the product.

1.2. Alcoholic beverages

The Idec/Nupens/UNC food labelling database did not include information on alcoholic beverages. Therefore, most frequent ingredients and percent composition for these products were estimated based on ingredient lists from supermarket websites published online, secondary data available in the literature (e.g. life cycle assessment studies), and other sources (e.g. reports from the food industry). See further details below.

Distilled spirits

Cachaça (a distilled spirit made from fermented sugarcane juice) was selected as a reference for this category given that it is the most frequently consumed distilled spirit in Brazil(7). This drink is made of a distilled fermented product obtained from sugarcane juice, sugar, and water(8). The proportion of sugarcane juice ('garapa' in Portuguese) used in the production of the distillate was obtained through the life cycle assessment conducted by Nigri et al.(9).

Wines

Most wines are made from grape juice (100%). Thus, the percent composition of this ingredient was assumed to be 100% of the product.

Beers

The most frequent ingredients and the percent composition of this alcoholic beverage was estimated based on the ingredient lists of the top three brands (Skol, Brahma and Antarctica) in Brazil according to the annual report of AMBEV - responsible for 67% of the market share in the country(10, 11).

APPENDIX 2: Food subgroups of industrially prepared multi-ingredient items.

Food subgroups (n=100)
smoked beef; salt-cured/dried beef; canned beef; reconstituted beef; processed poultry meat; smoked pork; salt-cured/dried pork; reconstituted/canned pork; smoked fish and seafood; salt-cured/dried fish and seafood; canned fish and seafood; canned vegetables; fruit jam; processed nuts and seeds; processed bread; processed cheese; beer; wine; sweet biscuits (regular/light/diet); salty snacks (regular/light); margarine and vegetable spreads (regular/light); baked goods (regular/light/diet); mass-produced packaged bread (regular/light/diet); soft drinks (regular/diet); chocolates (regular/light/diet); artificial juices and other sweetened beverages (regular/light); dairy drinks (regular/light/diet); ice cream (regular/diet); sauces (regular/light); breakfast cereals; cereal bars (regular/light/diet); chocolate milk (regular/light/diet); fruit jam (regular/diet); candies; syrups and toppings; gum (regular/light); powdered dessert (regular/diet); puddings, flans, and mousses (regular/diet); creams; confectionery; caramelized milk (regular/diet); peanut/nut candy (regular/diet); caramel; other sweets; ultra-processed cheese (regular/light); double cream (regular/light); condensed milk (regular/light/diet); ready-to-eat pasta; instant noodles (regular/light); ready-to-eat soups; ready-to-eat pizzas; sandwiches and wraps; fried and baked savoury meals; pies and pancakes; rice-based ready-to-eat meals; potato-based ready-to-eat meals; flour-based ready-to-eat meals; corn-based ready-to-eat meals; plant-based ready-to-eat meals; pork-based ready-to-eat meals; beef-based ready-to-eat meals; poultry-based ready-to-eat meals; fish-based ready-to-eat meals; ultra-processed beef meat; ultra-processed pork meat; ultra-processed poultry meat; ultra-processed fish and seafood meat; spirts; crackers; soy-based beverages; seasoning tablets/ready-to-eat condiments.

APPENDIX 3: Supplementary Information Text: Disaggregating single-ingredient animal-based foods into the plants and/or animals used as feed

The following methodological steps were taken for identifying the main types and total amount of plant-based ingredients required as feed inputs in the production of animal-based foods in Brazil (Figure S1).

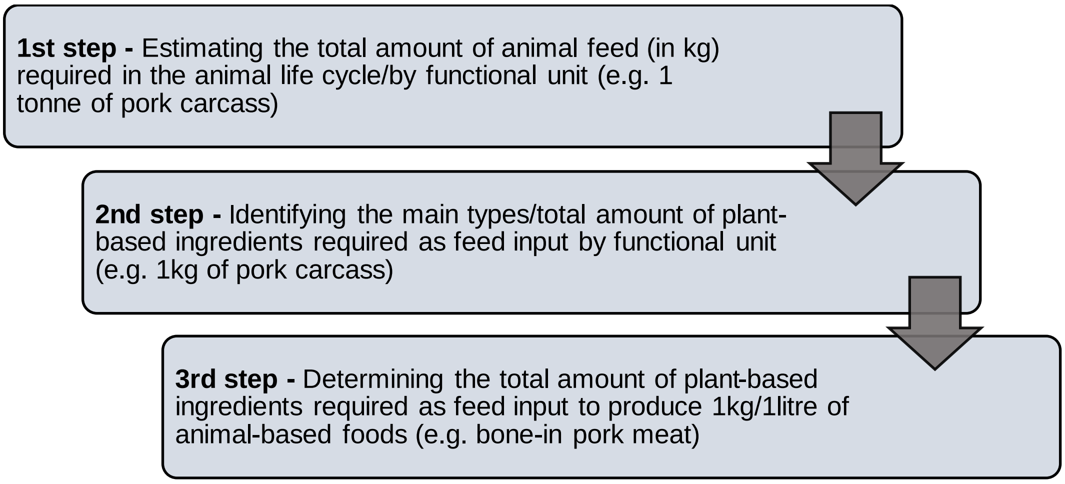


Figure S1. Methodological steps for disaggregating animal-based foods into the plant-based ingredients required as feed inputs in their production.

Further details on the analysis carried out for each group of herd are described below.

3.1 Pork meat

The feed requirement (in kg), as well as the main types and percent composition of plant species used as feed inputs in the production of 1 kg of pork carcass were based on the study carried out by Cherubini et al.(12). Then, the total amount of plant species required in the production of 1kg of bone-in and boneless pork meat was calculated by using conversion percentages from Wilfong & O'Quinn(13). For this, mean values of conversion percentages were applied (77.5% for bone-in and 67.5% for boneless meat) (see *Appendix 3*).

3.2 Poultry meat

Information on the feed requirement (in kg) and main types of ingredients used as feed inputs in the production of poultry meat was based on the study conducted by

González-García et al.(14) in Portugal. Given that 'maize' instead of 'wheat' is used as energy source in the Brazilian territory(15), the corresponding amount of 'wheat' provided by González-García et al(14). was computed as 'maize' in our analysis. Then, the total amount of plant species mobilized in the production of 1 kg of bone-in and boneless meat was calculated. For this, a correction factor of 2.4 was applied to take into account the mobilization of plant species when boneless poultry meat was acquired by Brazilian households (Appendix 3).

3.3 Chicken eggs

Estimates on the total amount (in kg) of plant species utilized as feed inputs in the production of hen eggs were based on the study conducted by Pelletier et al.(16) in Canada. This estimate was validated by Amaral et al.(17), who described the egg supply chain in the Brazilian context (primarily through intensive systems). The proportion of plant species used as feed inputs for laying hens were obtained through data from the Information Bulletin of the Brazilian Feed Industry Association (*Sindirações*), published in July 2019(18). Then, the total amount of plant species mobilized in the production of 1 kg of chicken eggs was calculated (see Appendix 3). These estimates were applied to all types of eggs cited in the 2017-18 HBS (e.g. quail eggs).

3.4. Farmed fish (Tilapia fish)

According to the Institute for Applied Economic Research (IPEA), tilapia is the main farmed fish produced in the Brazilian territory so this species was used as reference in our analysis(19). Estimates on the total amount of plant species used in tilapia farming were based on inventory data obtained by Yacout et al. (20), since as in Egypt, most part of the tilapia farming sector in Brazil is carried out in semi-intensive and intensive systems(21). The proportion of plant species used as feed inputs in Brazil was gathered from the Information Bulletin of the Brazilian Feed Industry Association (*Sindirações)* published in July 2019(18). These percentages were used to calculate the amount of each ingredient (in kg) required in the production of 1 kg of tilapia (live weight). According to Brum & Augusto(21), the average live weight of tilapia for slaughter is around 650g. Based on this information, the total amount of each plant-sourced ingredient required in the production of 1kg of tilapia carcass and filet was estimated. For this, average weights of tilapia carcass (497g) and filet (293g) provided by Silva et al.(22) were used. The estimates obtained through these steps were applied to all farmed fish available in the household expenditure dataset (see Appendix 3).

3.5. Farmed seafood (shrimp)

According to data from the Brazilian Institute of Geography and Statistics (IBGE, SIDRA), shrimp plays a prominent role in the Brazilian aquaculture, with a production of more than 56,000 tons in 2019(23). Therefore, this crustacean was selected to represent the farmed seafood category in the present study. Information on shrimp feed requirement (in kg) was based on the study conducted by Cao et al.(24), who investigated the environmental impact of semi-intensive production systems in China. According to Tahim et al.(25), this is the predominant production system in Brazil (particularly in the Northeast region, responsible for 99% of shrimp production in the country). The proportion of plant species used in shrimp feed formulations in the Brazilian territory was gathered from the Information Bulletin of the Brazilian Feed Industry Association (*Sindirações*) published in July 2019(18). Then, the amount of ingredients (in kg) required in the production of 1 kg of shell-on and cleaned shrimp was calculated. A correction factor of 4.10 was used to take into account the mobilization of plant species when cleaned shrimp was acquired by Brazilian households (see Appendix 3). Similar to farmed fish, the estimates obtained through these steps were applied to all farmed seafood available in the household expenditure dataset.

3.6. Beef meat

The beef supply chain is considered one of the most extensive and complex. Given Brazil's notoriety in this sector, a specific study was developed to estimate the total amount of animal feed (in kg) and main types of plant species used in the production of 1 kilogram (kg) of boneless beef by taking into account the predominant production systems in the Brazilian territory(26).

3.7. Cow's milk and dairy products (yoghurt, cheese, and butter)

Cow’s milk and dairy products were selected as reference since it is most frequently consumed by the Brazilian population(27).

3.7.1. Cow’s milk

The feed requirements estimated for beef cattle(26) were allocated to dairy cattle given the similarity of their diets in the Brazilian territory(28). For this, the feed requirements in natural matter for beef cattle (estimated over a period of 36 months) were calculated for one year (12 months), since the productivity of milk production systems is calculated annually. The main types and percent composition of plant species used as animal feed in the production of dairy cattle were based on data from the Information Bulletin of the Brazilian Feed Industry Association (*Sindiraçõe*s) published in July 2019(18). Then, the total amount of each food source was calculated taking into account the percentage shares of each breeding system in the Brazilian context (extensive: 32.8%, intensive and semi-extensive: 62.6% and confinement: 4.6%). Finally, the total amount of each plant species mobilized in the production of one litre of cow’s milk was estimated. Brachiaria and maize were chosen as reference categories for pasture and silage(26), respectively (see Appendix 3).

3.7.2. Dairy products

After identifying the main plant species mobilized in the production of one litre of cow's milk in the Brazilian context, the total amount of milk required in the production of most consumed dairy products (cheese, yogurt, and butter), as well as the amount of each plant species used in the production of these products were estimated (further details below). These estimates were applied to all types of cheeses and yogurts cited in the 2017-18 HBS (Appendix 3).

Cheese

According to Nigri et al.(29), for every kilogram of a traditional Brazilian cheese ("Minas" cheese) produced through artisanal and industrial systems, 8.7 and 8.8 litres of milk respectively are needed. Therefore, the average value (8.75 liters) was used in our analysis. Then, the total amount of plant species mobilized in the production of 1 kg of 'Minas’ cheese was estimated (Appendix 3).

Yogurt

According to Vasilaki et al.(30), 0.91 litre of milk are needed to produce 1 kg of plain yogurt. Based on this, the total amount of plant species mobilized in the production of one kilogram of natural yogurt was estimated (see Appendix 3).

Butter

Inventory data from life cycle assessment from Nilsson et al.(31) were used to estimate the amount of cow's milk required in the production of butter. According to the authors, for every 1kg of butter, 18.9 liters of milk are required(31). Based on this, the total amount of plant species mobilized in the production of 1kg of butter was calculated. However, considering that in addition to butter (1kg), other co-products are also obtained (e.g. 16.9kg of skimmed milk and 1kg of cream), it was necessary to estimate the allocation factor specifically associated to the butter fraction. For this, the following allocation factor (based on mass) was used(32):

$$\text{Allocation factor}_i = \frac{\text{mass of product } i}{\sum \text{mass of all products in the system}}$$

After applying the formula above, an allocation factor of 0.05 was obtained (allocation factor=1kg of butter/18.9kg of milk). Finally, the total amount of species mobilized in the production of 1kg of butter was calculated by multiplying the values obtained in the initial estimation by the allocation factor (see Appendix 3).

3.8 Meats from other confined animals

Meats from other animals cited in the 2017-17 HBS which used feed inputs in their lifecycle were classified into existing categories described in this protocol based on their characteristics and type of diets as following:

Other animals	**Category of reference**
Buffalo, goat, sheep, lamb	cattle
Boar, lowland paca	pork
ostrich	birds

APPENDIX 4

Table S1. Description of the main estimates obtained during disaggregation of animal-sourced foods into the plant-based ingredients used as feed inputs in the Brazilian territory.

	Step 1		Step 2		Step 3	
	Total amount of animal feed (kg)	**Functional unit**	**Total amount of plant-based ingredients (kg)**	**Functional unit**	**Total amount of plant-based ingredients (kg)**	**1kg/1litre of animal-sourced foods**
Pork meat	3,542.2[1]	1,000 kg of pork carcass	maize (2.3), soybean (0.98), rice (0.06)[1]	1 kg of pork carcass	maize (3.0/ 3.4), soybean (1.3/ 1.5), rice (0.1/ 0.1)	1 kg of bone-in/ boneless pork[2]
Poultry meat	2.6[3]	1.2 kg of chicken meat ready for distribution	maize (1.4)[ʃ], soybean (1.2)	1.2 kg of chicken meat ready for distribution	maize (1.1/ 2.7), soybean (1.0/ 2.4)	1 kg of bone-in/ boneless poultry meat[4]
Chicken eggs/other eggs	2,000[5]	1 ton of hen eggs	maize (1.3), soybean (0.4), sorghum (0.0), wheat (0.0)[6]	1 kg of chicken eggs	maize (1.3), soybean (0.4)	1 kg of chicken eggs[§]
Farmed fish (tilapia)	1,400[7]	1 ton of tilapia (live weight)	maize (0.4), soybean (0.1), wheat (0.3), sorghum (0.1)[6]	1 kg of tilapia (live weight)	maize (0.5/ 0.8), soybean (0.1/ 0.2), wheat (0.3/ 0.6), sorghum (0.1/ 0.2)	1kg of carcass/ fillet[8]
Farmed seafood (shrimp)	970[9]	1 ton of shrimp (live weight)	maize (0.3), soybean (0.1), wheat (0.2), sorghum (0.1)[6]	1 kg of shrimp (live-weight)	maize (0.3/ 1.1), soybean (0.1/ 0.2), wheat (0.2/ 0.7), sorghum (0.1/ 0.3)	1 kg of shell-on/ cleaned shrimp[10]
Beef meat	17,079.03[11]	1 Animal Brazil (36 months)[†]	brachiaria (72.1), maize (0.9), soybean (0.2), cotton (0.1), sorghum (0.1), wheat (0.0)	1 kg of bone-in beef (carcass weight)	brachiaria (101.4), maize (1.7), soybean (0.3), cotton (0.2), sorghum (0.1)	1 kg of boneless beef
cow’s milk	5,074.1[12]	1 Animal Brazil (12 months)	NA	NA	brachiaria (2.3), maize (0.6), soybean (0.1), cotton (0.0), sorghum (0.0)	1 litre of cow’s milk

	Step 1		Step 2		Step 3	
	Total amount of animal feed (kg)	**Functional unit**	**Total amount of plant-based ingredients (kg)**	**Functional unit**	**Total amount of plant-based ingredients (kg)**	**1kg/1litre of animal-sourced foods**
cheese	5,074.1[12]	1 Animal Brazil (12 months)	NA	NA	brachiaria (20.3), maize (5.3), soybean (0.6), cotton (0.1), sorghum (0.0), wheat (0.0)	1 kg of cheese
butter	5,074.1[12]	1 Animal Brazil (12 months)	NA	NA	brachiaria (2.2), maize (0.6), soybean (0.1), cotton (0.0), sorghum (0.0), wheat (0.0)	1 kg of butter
yogurt	5,074.1[12]	1 Animal Brazil (12 months)	NA	NA	brachiaria (2.1), maize (0.6), soybean (0.1), cotton (0.0), sorghum (0.0), wheat (0.0)	1 kg of plain yogurt

[ʃ] Maize instead of wheat is used as energy source in the Brazilian territory (Prudêncio da Silva et al. 2014). Therefore, the corresponding amount of wheat was computed as maize
[§] These estimates were applied to all types of eggs cited in the 2017-18 HBS (e.g. quail eggs)
[1] Based on Cherubini et al. (2015), Table A1, supplementary material
[2] Conversion percentages based on Wilfong & O'Quinn (2018). Mean values of conversion percentages were applied (77.5% for bone-in and 67.5% for boneless meat)
[3] Based on González-García et al. (2014), Table 2, p. 128
[4] After applying a correction factor = 2.38 (https://docs.ufpr.br/~monica.anjos/Fatores.pdf)
[5] Based on Pelletier et al. (2017), Table 1, p. 173. This estimate was also reported by Amaral et al. (2014), who described the egg supply chain in the Brazilian context
[6] Based on the Information Bulletin of the Brazilian Feed Industry Association (July 2019)
[7] Based on Yacout et al. (2016), Table 3. This decision was made given that most part of the tilapia farming sector in Brazil is carried out in semi-intensive and intensive systems (Institute for Applied Economic Research – IPEA, 2017)
[8] Average slaughter weight=650g, carcass weight=497g, filet weight=293g according to Brum & Augusto (2015) and Silva et al (2009)
[9] Based on Cao et al. (2011), Table 1, p. 6533
[10] After applying a correction factor = 4.1 (https://docs.ufpr.br/~monica.anjos/Fatores.pdf)
[11] Based on Fortes et al (2021)
[†] An animal that represents the different production systems applied in Brazil (extensive, semi intensive, and intensive): slaughter weight=463, slaughter age:36 months
[12] The feed requirements used for beef cattle were allocated to dairy cattle given the similarity of their diets. However, the feed requirements in natural matter for beef cattle were estimated for one year, since the productivity of milk production systems is calculated annually.
NA: not applicable, since main types/total amount of species for these products were based on estimates from the beef cattle category.

APPENDIX 5

Table S2. Plant and animal species and other organisms underlying Brazilian food purchase data (2017-2018 Household Budget Survey).

Generic name	**Scientific nomenclature**	**Kingdom**
avocado	*Persea americana* Mill.	Plantae
pineapple	*Ananas comosus* (L.) Merr.	Plantae
pumpkin	*Cucurbita maxima* Duchesne	Plantae
crookneck squash	*Cucurbita moschata* Duchesne	Plantae
zucchini	*Cucurbita pepo* L.	Plantae
turmeric	*Curcuma longa* L.	Plantae
açai palm	*Euterpe oleracea* Mart.	Plantae
barbados cherry	*Malpighia emarginata* DC.	Plantae
watercress	*Nasturtium officinale* R.Br.	Plantae
celery	*Apium graveolens* L.	Plantae
artichoke	*Cynara cardunculus L.*	Plantae
rosemary	*Salvia rosmarinus* Spenn.	Plantae
lettuce	*Lactuca sativa* L.	Plantae
alfalfa	*Medicago sativa* L.	Plantae
laver	*Pyropia* J.Agardh	Protista
cotton	*Gossypium hirsutum* L.	Plantae
garlic	*Allium sativum* L.	Plantae
leek	*Allium ampeloprasum* L.	Plantae
chicory	*Cichorium intybus* L.	Plantae
plum	*Prunus domestica* L.	Plantae
almond	*Prunus dulcis* (Mill.) D.A.Webb	Plantae
peanuts	*Arachis hypogaea* L.	Plantae
blackberry	*Morus nigra* L.	Plantae
basionym	*Alibertia edulis* (Rich.) A.Rich.	Plantae
cattley guava	*Psidium cattleianum* Sabine	Plantae
arrowroot	*Maranta arundinacea* L.	Plantae
rice	*Oryza sativa* L.	Plantae
rue	*Ruta graveolens* L.	Plantae
asparagus	*Asparagus officinalis* L.	Plantae
atemoya	*Annona squamosa* L.	Plantae
oat	*Avena sativa* L.	Plantae
hazelnut	*Corylus avellana* L.	Plantae
roselle	*Hibiscus sabdariffa* L.	Plantae
babassu	*Attalea speciosa* Mart.	Plantae
bacaba	*Oenocarpus distichus* Mart.	Plantae
bacury	*Platonia insignis* Mart.	Plantae
banana	*Musa acuminata* Colla	Plantae

Generic name	**Scientific nomenclature**	**Kingdom**
plantain	*Musa × paradisiaca* L.	Plantae
Barbatimão	*Stryphnodendron adstringens* (Mart.) Coville	Plantae
greater burdock	*Arctium lappa* L.	Plantae
arracacha	*Arracacia xanthorrhiza* Bancr.	Plantae
sweet potato	*Ipomoea batatas* (L.) Lam.	Plantae
potato	*Solanum tuberosum* L.	Plantae
yacon	*Smallanthus sonchifolius* (Poepp. & Endl.) H.Rob.	Plantae
common purslane	*Portulaca oleracea* L.	Plantae
aubergine	*Solanum melongena* L.	Plantae
malabar spinach	*Basella alba* L.	Plantae
beets, chards	*Beta vulgaris* L.	Plantae
sweet-sop	*Annona mucosa* Jacq.	Plantae
goat	*Capra hircus (*Linnaeus, 1758)	Animalia
forskohlii	*Coleus barbatus* (Andrews) Benth. ex G.Don	Plantae
cow	*Bos taurus (*Linnaeus, 1758)	Animalia
brachiaria	*Urochloa brizantha* (A.Rich.) R.D.Webster	Plantae
broccoli	*Brassica cretica* Lam.	Plantae
mung beans	*Vigna radiata* (L.) R.Wilczek	Plantae
buffalo	*Bubalus bubalis* (Linnaeus, 1758)	Animalia
mauritia	*Mauritia flexuosa* L.f.	Plantae
gourd, bottle gourd	*Lagenaria siceraria* (Molina) Standl.	Plantae
cocoa bean	*Theobroma cacao* L.	Plantae
coffee	*Coffea arabica* L.	Plantae
ambarella	*Spondias dulcis* Parkinson	Plantae
cashew	*Anacardium occidentale* L.	Plantae
prawn	*Penaeus brasiliensis* Latreille, 1817	Animalia
freshwater prawn	*Macrobrachium brasiliense* (Heller, 1862)	Animalia
chamomile	*Matricaria chamomilla* L.	Plantae
sugarcane	*Saccharum officinarum* L.	Plantae
cinnamon bark	*Cinnamomum verum* J.Presl	Plantae
canela-de-velho	*Miconia albicans (Sw.) Steud.*	Plantae
rape	*Brassica napus* L.	Plantae
Brazilian fireweed	*Erechtites valerianifolius* (Link ex Spreng.) DC.	Plantae
lemon grass	*Cymbopogon citratus* (DC.) Stapf	Plantae
Indian cress	*Tropaeolum majus* L.	Plantae
kaki	*Diospyros kaki* L.f.	Plantae
Indian yam	*Dioscorea trifida* L.f.	Plantae
star pickle	*Averrhoa carambola* L.	Plantae
snail	Pomacea bridgesii (Reeve, 1856)	Animalia
swamp ghost crab	*Ucides cordatus* (Linnaeus, 1763)	Animalia
sheep	*Ovis aries (*Linnaeus, 1758)	Animalia

Generic name	Scientific nomenclature	Kingdom
carqueja	*Baccharis crispa* Spreng.	Plantae
guernsey pigweed	*Amaranthus blitum* L.	Plantae
cascara	*Frangula purshiana* (DC.) A.Gray ex J.G.Cooper	Plantae
baumann's Horse chestnut	*Aesculus hippocastanum* L.	Plantae
Brazil nut	*Bertholletia excelsa* Bonpl.	Plantae
sweet chestnut	*Castanea sativa* Mill.	Plantae
catolé	*Syagrus cearensis* Noblick	Plantae
horsetail	*Equisetum arvense* L.	Plantae
onion	*Allium cepa* L.	Plantae
chives	*Allium schoenoprasum* L.	Plantae
carrot	*Daucus carota* L.	Plantae
rye	*Secale cereale* L.	Plantae
cherry	*Prunus avium* (L.) L.	Plantae
barley	*Hordeum vulgare* L.	Plantae
green tea	*Camellia sinensis (L.) Kuntze*	Plantae
chia seed	*Salvia hispanica* L.	Plantae
endive	*Cichorium endivia* L.	Plantae
chayote	*Sicyos edulis* Jacq.	Plantae
Spanish plum	*Spondias purpurea* L.	Plantae
coconut	Cocos nucifera L.	Plantae
quail	Coturnix coturnix (Linnaeus, 1758)	Animalia
coriander	*Coriandrum sativum* L.	Plantae
mushroom	*Agaricus sylvaticus* Schaeff.	Fungi
shitake	*Lentinula edodes* (Berk.) Pegler	Fungi
achiote	*Bixa orellana* L.	Plantae
cumin	*Cuminum cyminum* L.	Plantae
chinese cabbage	*Brassica rapa* L.	Plantae
collard grens, cabbage, cauliflower	*Brassica oleracea* L.	Plantae
cranberry	*Vaccinium macrocarpom* Aiton	Plantae
clove	*Syzygium aromaticum* (L.) Merr. & L.M. Perry	Plantae
cupuassu	*Theobroma grandiflorum* (Willd. ex Spreng.) K.Schum.	Plantae
curry	*Murraya koenigii* (L.) Spreng.	Plantae
oil palms	*Elaeis guineensis* Jacq.	Plantae
dill	*Anethum graveolens* L.	Plantae
lemon balm	*Melissa officinalis* L.	Plantae
brazilian tea	*Ilex paraguariensis* A.St.-Hil.	Plantae
African basil	*Ocimum gratissimum* L.	Plantae
fennel	*Foeniculum vulgare* Mill.	Plantae
lemon beebrush	*Aloysia citrodora* Paláu	Plantae
pea	*Lathyrus oleraceus* Lam	Plantae

Generic name	**Scientific nomenclature**	**Kingdom**
spinach	*Spinacia oleracea* L.	Plantae
holythorn	*Monteverdia aquifolium* (Mart.) Biral	Plantae
star anise	*Illicium verum* Hook.f.	Plantae
flooded-gum	*Eucalyptus grandis* W.Hill	Plantae
broad bean	*Phaseolus lunatus* L.	Plantae
bean	*Phaseolus vulgaris* L.	Plantae
pigeon pea	*Cajanus cajan* (L.) Huth	Plantae
adzuki bean	*Vigna angularis* (Willd.) Ohwi & H.Ohashi	Plantae
black-eyed pea	*Vigna unguiculata* (L.) Walp.	Plantae
fig	*Ficus carica* L.	Plantae
raspberry	*Rubus idaeus* L.	Plantae
chicken	*Gallus gallus* (Linnaeus, 1758)	Animalia
breadfruit	*Artocarpus altilis* (Parkinson) Fosberg	Plantae
ginger	*Zingiber officinale* Roscoe	Plantae
genip	*Genipa americana* L.	Plantae
sesame seed	*Sesamum indicum* L.	Plantae
sunflower	*Helianthus annuus* L.	Plantae
guava	*Psidium guajava* L.	Plantae
goji berry	*Lycium barbarum* L.	Plantae
chickpea	*Cicer arietinum* L.	Plantae
soursop	*Annona muricata* L.	Plantae
guaco	*Mikania micrantha* Kunth	Plantae
cocoplum	*Chrysobalanus icaco* L.	Plantae
guarana	*Paullinia cupana* Kunth	Plantae
Guavira	*Campomanesia adamantium* (Cambess.) O. Berg	Plantae
guinea fowl	*Numida meleagris* (Linnaeus, 1758)	Animalia
hibiscus	*Hibiscus rosa-sinensis* L.	Plantae
mint	*Mentha spicata* L.	Plantae
inga	*Inga capitata* Desv.	Plantae
yam	*Colocasia esculenta* (L.) Schott	Plantae
grapetree	*Plinia cauliflora* (Mart.) Kausel	Plantae
jackfruit	*Artocarpus heterophyllus* Lam.	Plantae
alligator	*Paleosuchus palpebrosus* (Cuvier, 1807)	Animalia
malabar plum	*Syzygium jambos* (L.) Alston	Plantae
paracress	*Acmella oleracea* (L.) R.K.Jansen	Plantae
wild swine	*Sus scrofa* Linnaeus, 1758	Animalia
gilo	*Solanum aethiopicum L.*	Plantae
jurubeba	*Solanum scuticum* M.Nee	Plantae
kumquat	*Citrus japonica* Thunb.	Plantae
kiwi	*Actinidia chinensis* Planch.	Plantae
lobster	*Panulirus argus* (Latreille, 1804)	Animalia

Generic name	Scientific nomenclature	Kingdom
orange	*Citrus × aurantium* L.	Plantae
lentil	*Vicia lens* (L.) Coss. & Germ.	Plantae
yeast	*Saccharomyces cerevisiae* (Desm.) Meyen	Fungi
leechee	*Litchi chinensis* Sonn.	Plantae
licuri palm	*Syagrus coronata* (Mart.) Becc.	Plantae
lime	*Citrus ×aurantiifolia* (Christm.) Swingle	Plantae
rangpur lime, lemon	*Citrus ×limon* (L.) Osbeck	Plantae
linseed	*Linum usitatissimum* L.	Plantae
bay	*Laurus nobilis* L.	Plantae
squid	*Doryteuthis pleii* (Blainville, 1823)	Animalia
hop	*Humulus lupulus* L.	Plantae
apple	*Malus domestica (Suckow) Borkh.*	Plantae
macela	*Achyrocline satureioides (Lam.) DC.*	Plantae
papaya	*Carica papaya* L.	Plantae
cassava	*Manihot esculenta* Crantz	Plantae
mango	*Mangifera indica* L.	Plantae
mangabeira	*Hancornia speciosa* Gomes	Plantae
mangosteen	*Garcinia mangostana* L.	Plantae
basil	*Ocimum basilicum* L.	Plantae
marjoram	*Origanum majorana* L.	Plantae
passion fruit	*Passiflora edulis* Sims	Plantae
maraja palm	*Bactris maraja* Mart.	Plantae
umari	*Poraqueiba sericea* Tul.	Plantae
fameflower	*Talinum paniculatum* (Jacq.) Gaertn.	Plantae
mussel	*Limnoperna fortunei* (Dunker, 1857)	Animalia
mallard	*Netta erythrophthalma* (Wied-Neuwied, 1833)	Animalia
wormseed (Mexican-tea)	*Dysphania ambrosioides* (L.) Mosyakin & Clemants	Plantae
maroon cucumber	*Cucumis anguria* L.	Plantae
honey	*Apis mellifera* Linnaeus, 1758	Animalia
watermelon	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	Plantae
melon (Cantaloupe)	*Cucumis melo* L.	Plantae
bitter melon	*Momordica charantia L.*	Plantae
maize	*Zea mays* L.	Plantae
blueberry	*Vaccinium myrtillus* L.	Plantae
strawberry	*Fragaria vesca* L.	Plantae
mustard greens	*Brassica juncea* (L.) Czern.	Plantae
baobad	*Adansonia digitata* L.	Plantae
nance	*Trichilia pallida* Sw.	Plantae
field mustard	*Brassica rapa* L.	Plantae
tataupa tinamou	*Crypturellus tataupa* (Temminck, 1815)	Animalia

Generic name	Scientific nomenclature	Kingdom
loquat	*Eriobotrya japonica* (Thunb.) Lindl.	Plantae
walnut	*Juglans regia* L.	Plantae
nutmeg	*Myristica fragrans Houtt.*	Plantae
Olive	*Olea europaea* L.	Plantae
barbados gooseberry	Pereskia aculeata Mill.	Plantae
oregano	*Origanum vulgare* L.	Plantae
oyster	*Magallana gigas* (Thunberg, 1793)	Animalia
common sturgeon	*Acipenser sturio* Linnaeus, 1758	Animalia
owland paca	*Cuniculus paca* (Linnaeus, 1766)	Animalia
heart of palm	*Euterpe edulis* Mart.	Plantae
patawa	*Oenocarpus bataua* Mart.	Plantae
duck	*Cairina moschata* (Linnaeus, 1758)	Animalia
Brazilian codling	*Urophycis brasiliensis* (Kaup, 1858)	Animalia
pearl cichlid	*Geophagus brasiliensis* (Quoy & Gaimard, 1824)	Animalia
armored catfishes	*Hypostomus affinis* (Steindachner, 1877)	Animalia
Atlantic needlefish	*Strongylura marina* (Walbaum, 1792)	Animalia
Atlantic sailfish	*Istiophorus albicans* (Latreille, 1804)	Animalia
bluefish	*Pomatomus saltatrix* (Linnaeus, 1766)	Animalia
rainbow runner	*Elagatis bipinnulata* (Quoy & Gaimard, 1825)	Animalia
banded leporinus	*Leporinus fasciatus* (Bloch, 1794)	Animalia
largespot river stingray	*Potamotrygon falkneri* (Castex & Maciel, 1963)	Animalia
silver arowana	*Osteoglossum bicirrhosum* (Cuvier, 1829)	Animalia
tuna	*Thunnus alalunga* (Bonnaterre, 1788)	Animalia
Cod	*Gadus macrocephalus* (Tilesius, 1810)	Animalia
thorny catfish	*Acanthodoras depressus* (Steindachner, 1881)	Animalia
black rockfish	*Mycteroperca bonaci* (Poey, 1860)	Animalia
mekong giant catfish	*Pangasianodon gigas* (Chevey, 1931)	Animalia
great barracuda	*Sphyraena barracuda* (Edwards, 1771)	Animalia
Amazon sailfin catfish	*Pterygoplichthys pardalis* (Castelnau, 1855)	Animalia
Atlantic bonito	*Sarda sarda* (Bloch, 1793)	Animalia
sandbar shark	*Carcharhinus plumbeus* (Nardo, 1827)	Animalia
Atlantic tarpon	*Megalops atlanticus* (Valenciennes, 1847)	Animalia
caitipa mojarra	*Diapterus rhombeus* (Cuvier, 1829)	Animalia
common carp	*Cyprinus carpio* (Linnaeus, 1758)	Animalia
sand drum	*Umbrina coroides* (Cuvier, 1830)	Animalia
king mackerel	*Scomberomorus cavalla* (Cuvier, 1829)	Animalia
chub mackerel	*Scomber japonicus* (Houttuyn, 1782)	Animalia
snowy grouper	*Hyporthodus niveatus* (Valenciennes, 1828)	Animalia
mutton snapper	*Lutjanus analis* (Cuvier, 1828)	Animalia
Pink cusk-eel	*Genypterus brasiliensis* (Regan, 1903)	Animalia
barred grunt	*Conodon nobilis* (Linnaeus, 1758)	Animalia

Generic name	Scientific nomenclature	Kingdom
salmon-bass	*Argyrosomus regius* (Asso, 1801)	Animalia
streaked prochilod	*Prochilodus lineatus* (Valenciennes, 1837)	Animalia
gilt-head bream	*Sparus aurata* (Linnaeus, 1758)	Animalia
jaw characin	*Salminus brasiliensis* (Cuvier, 1816)	Animalia
dolphinfish	*Coryphaena hippurus* (Linnaeus, 1758)	Animalia
piraíba fish	*Brachyplatystoma filamentosum* (Lichtenstein, 1819)	Animalia
lookdown fish	*Selene vomer* (Linnaeus, 1758)	Animalia
dusky grouper	*Epinephelus marginatus* (Lowe, 1834)	Animalia
rock hind	*Epinephelus adscensionis* (Osbeck, 1765)	Animalia
horse-eye jack	*Caranx latus* (Agassiz, 1831)	Animalia
largehead hairtail	*Trichiurus lepturus* (Linnaeus, 1758)	Animalia
South American catfish	*Rhamdia quelen* (Quoy & Gaimard, 1824)	Animalia
spotted hoplo	*Megalechis thoracata* (Valenciennes, 1840)	Animalia
lenticulata pike cichlid	*Crenicichla lenticulata* (Heckel, 1840)	Animalia
Silver prochilodus	*Semaprochilodus taeniurus* (Valenciennes, 1821)	Animalia
hoplias aimara	*Hoplerythrinus unitaeniatus* (Spix & Agassiz, 1829)	Animalia
two-spot tetra	*Astyanax bimaculatus* (Linnaeus, 1758)	Animalia
Patagonian flounder	*Paralichthys patagonicus* (Jordan, 1889)	Animalia
driftwood catfish	*Ageneiosus inermis* (Linnaeus, 1766)	Animalia
broadband anchovy	*Anchoviella lepidentostole* (Fowler, 1911)	Animalia
highwaterman catfish	*Hypophthalmus edentatus* (Spix & Agassiz, 1829)	Animalia
red-tailed brycon	*Brycon cephalus* (Günther, 1869)	Animalia
Argentine hake	*Merluccius hubbsi* (Marini, 1933)	Animalia
spotted moray	*Gymnothorax moringa* (Cuvier, 1829)	Animalia
namorado sandperch	*Pseudopercis numida* (Miranda Ribeiro, 1903)	Animalia
pacu	*Piaractus mesopotamicus* (Holmberg, 1887)	Animalia
Atlantic bumper	*Chloroscombrus chrysurus* (Linnaeus, 1766)	Animalia
Southern kingfish	*Menticirrhus americanus* (Linnaeus, 1758)	Animalia
bluespotted seabream	*Pagrus caeruleostictus* (Valenciennes, 1830)	Animalia
stonefish	*Synanceia verrucosa* (Bloch & Schneider, 1801)	Animalia
grey triggerfish	*Balistes capriscus* (Gmelin, 1789)	Animalia
acoupa weakfish	*Cynoscion acoupa* (Lacepède, 1801)	Animalia
smooth weakfish	*Cynoscion leiarchus* (Cuvier, 1830)	Animalia
piapara fish	*Leporinus obtusidens (Valenciennes, 1837)*	Animalia
spotted sorubim	*Pseudoplatystoma corruscans* (Spix & Agassiz, 1829)	Animalia
piracanjuba fish	*Brycon orbignyanus* (Valenciennes, 1850)	Animalia
vulture catfish	*Calophysus macropterus* (Lichtenstein, 1819)	Animalia
laulao catfish	*Brachyplatystoma vaillantii* (Valenciennes, 1840)	Animalia
coroatá	*Platynematichthys notatus* (Jardine, 1841)	Animalia

Generic name	**Scientific nomenclature**	**Kingdom**
red piranha	*Pygocentrus nattereri* (Kner, 1858)	Animalia
red-bellied pacu	*Piaractus brachypomus* (Cuvier, 1818)	Animalia
redtail catfish	*Phractocephalus hemioliopterus* (Bloch & Schneider, 1801)	Animalia
pirarucu fish	*Arapaima gigas* (Schinz, 1822)	Animalia
Alaska pollock	*Gadus chalcogrammus* (Pallas, 1814)	Animalia
white mullet	*Mugil curema* (Valenciennes, 1836)	Animalia
common snook	*Centropomus undecimalis* (Bloch, 1792)	Animalia
toothless characins	*Cyphocharax gilbert* (Quoy & Gaimard, 1824)	Animalia
salmon	*Salmo salar* (Linnaeus, 1758)	Animalia
European pilchard	*Sardina pilchardus* (Walbaum, 1792)	Animalia
Brazilian sardinella	*Sardinella brasiliensis* (Steindachner, 1879)	Animalia
saardine fish	*Triportheus nematurus* (Kner, 1858)	Animalia
smalltooth sawfish	*Pristis pectinata* (Latham, 1794)	Animalia
the black pacu	*Colossoma macropomum* (Cuvier, 1816)	Animalia
wolf fish	*Hoplias malabaricus* (Bloch, 1794)	Animalia
brown trout	*Salmo macrostigma* (Duméril, 1858)	Animalia
butterfly peacock bass	*Cichla ocellaris* (Bloch & Schneider, 1801)	Animalia
the rose fish	*Sebastes norvegicus* (Ascanius, 1772)	Animalia
shortnose guitarfish	*Zapteryx brevirostris* (Müller & Henle, 1841)	Animalia
crevalle jack	*Caranx hippos* (Linnaeus, 1766)	Animalia
blue runner	*Caranx crysos* (Mitchill, 1815)	Animalia
gafftopsail catfish	*Bagre marinus* (Mitchill, 1815)	Animalia
yellow tail barracuda	*Acestrorhynchus falcirostris* (Cuvier, 1819)	Animalia
cucumber	*Cucumis sativus* L.	Plantae
souari nut	*Caryocar villosum* (Aubl.) Pers.	Plantae
pear	*Pyrus communis* L.	Plantae
turkey	*Meleagris gallopavo* Linnaeus, 1758	Animalia
peach	*Prunus persica* (L.) Batsch	Plantae
physalis	*Physalis peruviana* L.	Plantae
black peper	*Piper nigrum* L.	Plantae
pepper, paprika	*Capsicum annuum* L.	Plantae
Brazilian pine	*Araucaria angustifolia* (Bertol.) Kuntze	Plantae
pine	*Pinus pinea* L.	Plantae
pistachio	*Pistacia vera* L.	Plantae
dragon fruit	*Selenicereus undatus* (Haw.) D.R.Hunt	Plantae
surinam cherry	*Eugenia uniflora* L.	Plantae
pitomba	*Talisia cerasina* (Benth.) Radlk.	Plantae
pennyroyal/mosquito plant	*Mentha pulegium L.*	Plantae
octopus	*Octopus vulgaris* (Cuvier, 1797)	Animalia
peach palm	*Bactris gasipaes* Kunth	Plantae

Generic name	**Scientific nomenclature**	**Kingdom**
okra	*Abelmoschus esculentus* (L.) Moench	Plantae
quinoa	*Chenopodium quinoa* Willd.	Plantae
radish	*Raphanus sativus* L.	Plantae
rambutan	*Nephelium lappaceum* L.	Plantae
pomegranate	*Punica granatum* L.	Plantae
wild rocket	*Eruca vesicaria* (L.) Cav.	Plantae
parsley	*Petroselinum crispum* (Mill.) Fuss	Plantae
common sage	*Salvia officinalis* L.	Plantae
sapodilla / naseberry fruit	*Manilkara zapota* (L.) P.Royen	Plantae
senna	*Senna alexandrina* Mill.	Plantae
common sowthistle	*Sonchus oleraceus* L.	Plantae
crab	*Callinectes sapidus* (Rathbun, 1896)	Animalia
soybean	*Glycine max* (L.) Merr	Plantae
sorghum	*Sorghum bicolor* (L.) Moench	Plantae
charru mussel	*Mytella strigata* (Hanley, 1843)	Animalia
arrowleaf elephant's ear	*Xanthosoma taioba* E.G.Gonç.	Plantae
tayuya	*Cayaponia tayuya* (Vell.) Cogn.	Plantae
tamarind	*Tamarindus indica* L.	Plantae
tangerine	*Citrus reticulata* Blanco	Plantae
yellow mombin	*Spondias mombin* L.	Plantae
tilapia	*Oreochromis niloticus* (Linnaeus, 1758)	Animalia
tomato	*Solanum lycopersicum* L.	Plantae
thyme	*Thymus vulgaris L.*	Plantae
yellow-spotted river turtle	*Podocnemis unifilis* (Troschel, 1848)	Animalia
sourgrass	*Oxalis articulata* Savigny	Plantae
woodsorrel	*Oxalis tetraphylla* Cav.	Plantae
wheat	*Triticum aestivum* L.	Plantae
turu	*Teredo navalis* (Linnaeus, 1758)	Animalia
Brazil plum	*Spondias tuberosa* Arruda	Plantae
fox grape	*Vitis labrusca* L.	Plantae
uxi-amarelo	*Endopleura uchi* (Huber) Cuatrec.	Plantae
scallop	*Pecten maximus* (Linnaeus, 1758)	Animalia

REFERENCES

1. Ricardo CZ, Peroseni IM, Mais LA, Martins APB, Duran AC. Trans Fat Labeling Information on Brazilian Packaged Foods. Nutrients. 2019;11(9).
2. Clark M, Springmann M, Rayner M, Scarborough P, Hill J, Tilman D, et al. Estimating the environmental impacts of 57,000 food products. Proceedings of the National Academy of Sciences of the United States of America. 2022;119(33):e2120584119.
3. Monteiro CA, Cannon G, Levy RB, Moubarac J, Louzada MLC, Rauber F, et al. Ultra-processed foods: what they are and how to identify them. Public Health Nutr. 2019;22(5):936-41.
4. Scapin T, Louie JCY, Pettigrew S, Neal B, Rodrigues VM, Fernandes AC, et al. The adaptation, validation, and application of a methodology for estimating the added sugar content of packaged food products when total and added sugar labels are not mandatory. Food Res Int. 2021;144:110329.
5. Pesquisa de Orçamentos Familiares 2008-2009: Tabelas de Composição Nutricional dos Alimentos Consumidos no Brasil. [Internet]. Instituto Brasileiro de Geografia e Estatística. 2011.
6. Pan American Health Organization (PAHO). Mean salt intake in adults aged 25 years and older in the Americas, 1990-2019: PAHO; 2023 [Available from: https://www.paho.org/en/enlace/salt-intake.
7. STATISTA. Distilled spirits market share in Brazil as of 2017, by type of beverage 2022 [Available from: https://www.statista.com/statistics/1008379/spirits-market-share-beverage-type-brazil/.
8. Pao de Acucar. Aguardente 51 PIRASSUNUNGA Garrafa 965ml 2023 [Available from: https://www.paodeacucar.com/produto/72566/aguardente-51-pirassununga-garrafa-965ml.
9. Nigri EM, Filho ER, Rocha SDF, Fari PE. Comparando processos industriais e artesanais: uma aplicação da análise simplificada do ciclo de vida na produção da cachaça. XXX ENCONTRO NACIONAL DE ENGENHARIA DE PRODUÇÃO; São Carlos2010.
10. Junior OC. Panoramas setoriais 2030: bebidas. BNDES; 2017.
11. AMBEV. Cervejas - Mapa de marcas 2020 [Available from: https://www.ambev.com.br/conteudo/uploads/2019/04/relat%C3%B3rio-de-sustentabilidade-ambev-2018.pdf.
12. Cherubini E, Zanghelini GM, Alvarenga RAF, Franco D, Soares SR. Life cycle assessment of swine production in Brazil: a comparison of four manure management systems. J Clean Prod. 2015;87:68-77.
13. Wilfong A, O'Quinn T. How Much Meat to Expect from Your Animal. Kansas State University; 2018.
14. González-García S, Gomez-Fernández Z, Dias AC, Feijoo G, Moreira MT, Arroja L. Life Cycle Assessment of broiler chicken production: a Portuguese case study. J Clean Prod. 2014;74:125-34.
15. da Silva VP, van der Werf HMG, Soares SR, Corson MS. Environmental impacts of French and Brazilian broiler chicken production scenarios: An LCA approach. Journal of Environmental Management. 2014;133:222-31.
16. Pelletier N. Life cycle assessment of Canadian egg products, with differentiation by hen housing system type. J Clean Prod. 2017;152:167-80.
17. Amaral GF, Guimarães D, Nascimento JC, Custodio S. Avicultura de postura: estrutura da cadeia produtiva, panorama do setor no Brasil e no mundo e o apoio do BNDES. Rio de Janeiro: BNDES setorial; 2016.
18. Sindicato Nacional da Indústria de Alimentação Animal (Sindirações). Boletim Informativo do Setor. Sindirações; 2019.
19. Schulter EP, Vieira Filho JER. Evolução da Psicultura no Brasil: Diagnóstico e desenvolvimento da cadeia produtiva de Tilápia. Rio de Janeiro: Instituto de Pesquisa Econômica Aplicada – ipea; 2017.

20. Yacout DMM, Soliman NF, Yacout MM. Comparative life cycle assessment (LCA) of Tilapia in two production systems: semi-intensive and intensive. The International Journal of Life Cycle Assessment. 2016;21(6):806-19.
21. Brum SA, Augusto POM. Ambiente de tarefa: as estratégias da COPACOL na produção de Tilápia em escala industrial pelo sistema vertical integrado. Revista Eletrônica Científica do CRA-PR. 2015;2(1):19-34.
22. Silva FV, Sarmento NLAF, Vieira JS, Tessitore AJA, Oliveira LLS, Saraiva EP. Características morfométricas, rendimentos de carcaça, filé, vísceras e resíduos em tilápias-do-nilo em diferentes faixas de peso. Revista Brasileira de Zootecnia. 2009;38(8):1407-12.
23. Instituto Brasileiro de Geografia e Estatística (IBGE). Pesquisa Pecuária Municipal. Tabela 3940 - Produção da aquicultura por tipo de produto. Rio de Janeiro: IBGE; 2019.
24. Cao L, Diana JS, Keoleian GA, Lai Q. Life cycle assessment of Chinese shrimp farming systems targeted for export and domestic sales. Environmental Science & Technology. 2011;45(15):6531-8.
25. Tahim EF, Damaceno MN, de Araújo IF. Trajetória Tecnológica e Sustentabilidade Ambiental na Cadeia de Produção da Carcinicultura no Brasil. Rev Econ Sociol Rural 2019;57(1):93-107.
26. Fortes MF, Leite FHM, Garzillo JMF, Monteiro CA. Analysis of the Impact of the Meat Supply Chain on the Brazilian Agri-Food System. SSRN. 2020.
27. Instituto Brasileiro de Geografia e Estatística (IBGE). Pesquisa de Orçamentos Familiares 2017-2018: avaliação nutricional da disponibilidade domiciliar de alimentos no Brasil. In: IBGE, editor. Rio de Janeiro2020.
28. Assis AG, Stock LA, Campos OF, Gomes AT, Zoccal R, Silva MR. Sistemas de produção de leite no Brasil. Brasilia: Embrapa; 2005.
29. Nigri EM, Barros AC, Rocha SDF, Filho ER. Assessing environmental impacts using a comparative LCA of industrial and artisanal production processes: "Minas Cheese" case. Food Sci Technol. 2014;34(3):522-31.
30. Vasilaki V, Katsou E, Ponsá S, Colón J. Water and carbon footprint of selected dairy products: A case study in Catalonia. J Clean Prod. 2016;139:504-16.
31. Nilsson K, Flysjö A, Davis J, Sim S, Unger N, Bell S. Comparative life cycle assessment of margarine and butter consumed in the UK, Germany and France. The International Journal of Life Cycle Assessment. 2010;15(9):916-26.
32. Ramirez PKS. Análise de métodos de alocação utilizados em avaliação do ciclo de vida. Florianópolis: Universidade Federal de Santa Catarina; 2009.

6. DIVERSIDADE DE ESPÉCIES VEGETAIS MOBILIZADAS POR AQUISIÇÕES DOMICILIARES DE ALIMENTOS NO BRASIL (2017-18): INFLUÊNCIA DA PARTICIPAÇÃO NA AQUISIÇÃO DE CARNE BOVINA E DE ALIMENTOS ULTRAPROCESSADOS

Este capítulo apresenta o manuscrito “Diversity of plant species mobilized by household food acquisitions in Brazil (2017-18): influence of the purchase share of beef and ultra-processed foods”, de autoria de Fernanda Helena Marrocos Leite, Neha Khandpur, Giovanna Calixto Andrade, Eurídice Martínez Steele, Josefa Maria Fellegger Garzillo, Renata Bertazzi Levy, Carlos Augusto Monteiro. O artigo será submetido para publicação na revista *Nature Sustainability* devendo o texto principal conter até 3.000 palavras (excluindo resumo, métodos, referências e tabelas/figuras).

Diversity of plant species mobilized by household food acquisitions in Brazil (2017-18): influence of the purchase share of beef and ultra-processed foods

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ABSTRACT

Background: Agrobiodiversity is essential for supporting healthier diets and moving towards more sustainable food systems. However, the worldwide spread of a 'globalised diet', characterised by increased consumption of animal-sourced foods and of ultra-processed foods poses a risk to agrobiodiversity.

Objective: This study aimed to investigate the impact of different patterns of ultra-processed food and beef acquisition on the diversity of plant species mobilized by household food purchases in Brazil.

Methods: Data from the 2017-18 National Household Budget Survey were used to quantify the total amount of foods purchased (in kg-person-year). Food items were classified according to the Nova system. A multi-step methodology was applied to estimate the plant species underlying household food acquisitions. The Shannon index was used to assess the diversity of plant species mobilized by Brazilian food purchases. Linear regression models were used to test associations between the purchase share of beef and of ultra-processed foods and the Shannon index.

Results: Six species accounted for more than 95% of the total amount of plant species required by Brazilian food purchases. This was reflected by a low value of the Shannon index (H=0.86; 0.84; 0.87). Highest purchase share of ultra-processed foods and of beef were associated with lower diversity of plant species mobilized when compared to the lowest quintile. The Shannon index decreased by 51% moving from a scenario with the lowest share of both ultra-processed foods and beef to total food acquisition to a scenario with the highest share of both food groups.

Conclusion: Our findings demonstrate that food acquisition patterns rich in beef and ultra-processed foods are associated with lower diversity of species mobilised by the Brazilian population when considering the most predominant production systems in the national territory.

Keywords: agrobiodiversity, beef, ultra-processed foods, Shannon index, Nova system, Brazil.

6.1. INTRODUCTION

Agrobiodiversity (or agricultural biodiversity) – defined as the 'variety and variability of animals, plants and other organisms used directly or indirectly for food and agriculture'(1) – is essential for supporting and diversifying agroecosystems, promoting healthy diets and moving towards more sustainable food systems(1, 2). Currently, the world is facing an unprecedented loss in the diversity of wild and cultivated species, particularly those of plant origin(3, 4). As of 2019, rice, wheat, and maize, accounted for more than 40% of total available food calories globally; with a limited number of other crops (cereals, legumes, roots/tubers and sugarcane out of fewer than 200 species) making up more than 75% of plant-sourced calories(5, 6).

Two main trends that characterize 'global diets' - the increasing production and consumption of animal-sourced foods and of ultra-processed foods at the expense of unprocessed/minimally processed, plant-sourced foods - may directly affect agrobiodiversity(7, 8).

Traditional cuisines combine a variety of plant-sourced foods (e.g. grains with legumes, cereals with vegetables, tubers with legumes) with smaller amounts of animal-sourced foods to add flavour and/or improve the nutritional composition of the overall diet(8, 9). However, 'global diets' are increasingly shifting towards incorporating more animal-sourced foods (including beef)(10, 11), often derived from animals fed on pasture and feed inputs from a small number of high-yield plant varieties(7). In Brazil, 104kg of animal feed from six plant species (brachiaria, maize, soybean, cotton, sorghum and wheat) are required to produce 1kg of boneless beef meat(12). Similarly, in the United States, national beef production chains rely on tonnes of feedlot rations made of five plant species: maize, sorghum, barley, oats and wheat(13). The high demand for monocultures and pastureland required in the production of beef through industrial livestock farming negatively impairs the production and consumption of a variety of plant-sourced foods, and poses a risk to agrobiodiversity(9, 11, 14).

Displacement of a variety of unprocessed/minimally processed foods and freshly prepared dishes and meals by ultra-processed foods – defined as ready-to-eat or heat formulations of food substances, mostly commodity ingredients, and cosmetic additives through a series of industrial processes(15) – also contributes to a lower agrobiodiversity. Dietary patterns rich in ultra-processed food products such as soft drinks, biscuits, salty snacks, pre-prepared pastas and dishes are not only associated with lower dietary diversity (measured by the minimum dietary diversity indicator)(16), but also highly based on ingredients extracted from a limited number of the same high-yielding plant species used for animal feed, including maize, wheat, soy and oil seed crops(7, 17, 18). Furthermore, ultra-processed meat products (e.g. chicken nuggets, hot dogs) put additional pressure to agricultural biodiversity since ingredients of animal origin usually come from confined animals that rely on the same high-yielding crops for animal feed(19). The underlying homogeneity of an increasingly prominent 'globalised diet' driven by industrial food systems is a clear symptom of deteriorating agrobiodiversity.

Although the contribution of beef to biodiversity loss has been acknowledged and is gaining global attention, research evaluating the impacts of ultra-processed diets on this domain is still lacking(7). At the time of writing, we found no studies investigating the simultaneous effects of ultra-processed food and beef consumption on agrobiodiversity. The fact that most ultra-processed foods contain multiple ingredients and their exact amount is not often provided on a products' ingredient list or made available by food manufactures is a key limitation when evaluating the environmental impacts of these products(20), including impacts on agrobiodiversity. Similarly, further studies are needed to assess the impacts of animal-sourced foods (including beef) on the diversity of species used as pasture and feed inputs in the animal life cycle(13).

Using nationally representative data from 2017-2018, this study aimed to investigate the impact of different patterns of ultra-processed food and beef acquisition on the diversity of plant species mobilized by household food purchases in Brazil.

6.2. METHODS

Data source and collection

The dietary data analysed in this study comprised 7-day food purchase records from the National Household Budget Survey (HBS), conducted by the Brazilian Institute of

Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* - IBGE) between July 2017 and July 2018(21). The 2017-18 HBS is the most recent nationally representative survey involving 57,920 Brazilian households selected using cluster sampling, in two stages: 1) random selection of census tracts; 2) random selection of households within those tracts. The census tracts were drawn from a Master Sample of Household Surveys or Common Sample (containing a pool of 12,800 tracts of the country) to obtain the strata of households with high geographic and socioeconomic homogeneity. Interviews were distributed uniformly in each selected stratum during the four quarters of the study year to capture seasonal variations in purchases of food and other products. A detailed description of the methodology and sampling process of the HBS is available in IBGE publications(21).

For the present study, the household clusters generated in the sampling plan (strata) were used as the unit of analysis (n=575). The mean number of households studied within each study unit was 86.5 (range: 16–524).

Classification of food items according to Nova

All food items acquired by the Brazilian households were identified through the 7-day food purchase records and converted into kilograms or litres by IBGE. Then, each registered food item received a unique code. Next, food items were classified according to the Nova system(15, 22) into four groups: 1) unprocessed or minimally processed foods (e.g. cereals, legumes, fruits, vegetables, meats), 2) processed culinary ingredients (e.g. as sugar, salt, vegetable oils, butter and lard), 3) processed foods (e.g. canned vegetables, salted nuts and seeds, freshly made unpackaged breads and cheeses), and 4) ultra-processed foods (e.g. sweetened or salty snacks, soft drinks, instant noodles, reconstituted meat products, pre-prepared pizza and pasta dishes, packaged breads, biscuits and confectionery); and into 128 mutually exclusive subgroups within each Nova group (see Appendix 1).

Quantification of ultra-processed food and beef acquisitions

First, the total amount of foods and beverages purchased by households during a 7-day period were converted into kilograms per year (kg-year). Then, in each stratum, we estimated the acquisition of unprocessed and minimally processed foods (group

1), processed culinary ingredients (group 2), processed foods (group 3), and ultra-processed foods (group 4) and subgroups within these four groups (in kg-person-year) by summing up the food items classified by the Nova system (in kg-year) of all households belonging to the same stratum and dividing by the total number of household members in the stratum. Subsequently, the weight proportion of Nova groups and subgroups (percentage of total food weight in kg-person-year) was calculated in each stratum.

The beef acquisition (in kg-person-year) was measured following a similar procedure. In each stratum, we estimated the acquisition of beef by summing up the total amount of unprocessed/minimally processed beef and beef offal (group 1); as well as the respective amount of beef used in the production of cured, smoked or pickled beef (group 3), reconstituted meat products and ready-to-eat dishes with beef (group 4) acquired by all households belonging to the same stratum (in kg-year). These amounts were then divided by the number of household members in the stratum to obtain the total acquired in kg-person-year. Thereafter, the weight proportion of beef (percentage of total food weight in kg-person-year) was calculated in each stratum.

Estimating the plant species underlying household food acquisitions

The methodological steps for identifying the plant species underlying household food acquisitions are described in detail in Leite et al(23). An overview of these steps is presented below:

Overview: Key steps for estimating the plant species underlying food purchase data.

Step 1. Identifying fit-for-purpose dietary data and compiling a food list

- A list of foods and beverages acquired by Brazilian households was compiled, with each registered food item receiving a unique code.

Step 2. Disaggregating multi-ingredient items into individual ingredients

- The species underlying subgroups of industrially prepared multi-ingredient items (including processed foods and ultra-processed foods) were identified from a national food labelling database. The ingredient composition of food subgroups was estimated using back-of-package nutritional information and other logic checks.

Step 3. Disaggregating single-ingredient animal-based foods into the plants and/or animals used as feed

- The main types and total amount of plant species used as pasture and feed inputs in the production of animal-based foods/ingredients in the Brazilian territory were estimated.

Step 4. Combining species-level data with dietary data

- Species level data were linked back to household data in weight proportion to the food products acquired by the Brazilian households.

Quantifying the total amount of mobilized plant species

Total amounts of unique plant species mobilized by household food acquisitions (in kg-person-year) were estimated by summing up the total amount of the respective species required by all households belonging to the same stratum, and dividing by the number of household members in the stratum. Subsequently, the total amount of all plant species required by each stratum (in kg-person-year) was calculated by summing up the amounts of each plant species mobilized by the stratum.

Diversity metric

The Shannon diversity index(24) (H, called the Shannon index henceforth) was chosen to assess the diversity of plant species required by Brazilian households. This metric reflects how many different types of plant species are mobilized by Brazilian household food acquisitions and how evenly these different types of species are distributed. It is derived as(24):

$$H = -\sum (p_i \times \ln p_i)$$

where, p_i is the relative abundance of each species, calculated as the total amount (in kg-person-year) of a species mobilized by each strata of households (ni) divided by the total amount (in kg-person-year) of all species mobilized by each strata of households (N): ni/N; and $\ln p_i$ is the natural logarithm of p_i.

The Shannon index increases both with the increase of species richness and the better weight distribution of species(25) in each stratum. The minimum value this metric can take is 0 (no diversity, i.e. 100% of the total amount of mobilized plant species in a stratum comes from exclusively one species), while the maximum value ($H_{max.}$) which represents maximum evenness, will depend directly on the number of species

identified in the sample (S); $H_{max.}$= ln(S). In the present study, higher values of H correspond to higher diversity of plant species mobilized by each stratum.
This index was chosen since it is one of the most widely applied measures of food biodiversity(25). It has been previously used to investigate the diversity of food supplies(26), food systems' biodiversity at the country level(27), and food production diversity(28, 29).

Data analysis

The mean Shannon index relative to the diversity of plant species mobilized by Brazilian household food acquisitions in 2017-2018 was estimated for the entire population and compared across sociodemographic stratum: per capita income (in quintiles), residential area (urban vs. rural) and macroregion (North, Northeast, Southeast, South and Midwest) using crude and adjusted linear regression models.

Then, the mean absolute total food, ultra-processed food and beef acquisitions (kg-person-year), and the share of ultra-processed foods and of beef (% of total food acquisitions) were calculated and compared across sociodemographic strata using linear regression models. The mean absolute (kg-person-year) and relative share (%) of acquired Nova food groups and subgroups such as fruits, meat, cheese, biscuits were estimated in the overall population.

Thereafter, we used restricted cubic splines in the multivariate linear regression models with four knots (20^{th}, 40^{th}, 60^{th}, 80^{th} centiles) to test the linearity of the association between the share of ultra-processed foods and of beef to total food acquisition, adjusting for area, region, income and total amount of food acquired (in kg).

Restricted cubic splines were also used in the multivariate linear regression models with four knots (20^{th}, 40^{th}, 60^{th}, 80^{th} centiles) to test the linearity of the association between both the share of ultra-processed foods and of beef to total food acquisition (exposure variables) and the Shannon index (outcome). Next, crude and adjusted linear regression models were used to evaluate the effect of quintiles of the share of ultra-processed foods and of beef to total food acquisition (% of total kilograms) on the

Shannon index. For both analyses, two adjusted models were run: Model 1 - adjusted for area, region, income and total amount of food acquired (in kg); and Model 2 – Model 1 + other exposure variable (the share of ultra-processed foods or of beef to total food acquisition, as applicable).

The simultaneous effect that ultra-processed food and beef acquisition exert on the diversity of plant species mobilized by Brazilian household aggregates was investigated. The interaction between exposures was tested and proved to be significant ($p<0.001$) so the effect that the simultaneous share of ultra-processed foods and beef exert on the Shannon index was evaluated.

Finally, the distributions (%) of the total amount of plant species in kilograms mobilized by annual household food acquisitions according to the lowest and highest share (Q1-low; Q5-high) of ultra-processed foods and of beef were estimated.

Linear trend and Bonferroni tests were used to investigate significant associations for ordinal and non-ordinal categorical variables, respectively. All analyses and graphs were performed using the software Stata/SE version 16.1 in the module survey, which takes into account the complex sample design of the 2017-18 IBGE survey. A p value ≤0.05 was used to identify statistical significance.

6.3. RESULTS

The average Shannon index relative to the diversity of plant species that underlie household food acquisitions in Brazil was 0.86 (**Table 1**). The maximum value that the Shannon index could reach in our sample would be 5.42, representing maximum diversity (i.e. if all the 225 mobilized plant species were evenly distributed). Only six species (brachiaria, maize, soybean, rice, sugarcane and wheat) accounted for more than 95% of the total amount of plant species required by Brazilian household food acquisitions in 2017-18 (data not shown). **Table 1** describes the Shannon index across sociodemographic strata of the Brazilian population.

The average total amount of foods acquired by Brazilian households in 2017-18 was 263.6 kg-person-year, and approximately a quarter (24.7%) of the total amount of purchased food (in kg-person-year) came from ultra-processed foods, while 5.4% came from beef (**Table 2**). Unprocessed and minimally processed foods contributed 59.5% of household food acquisitions, processed foods an additional 8.4% and processed culinary ingredients the remaining 7.4% (**Table S1**).

Figure 1 shows an inverse linear association between the shares of ultra-processed foods and of beef to total food acquisition in Brazilian households, using restricted cubic spline adjusted regression model. Overall, each increase of 6 percentage points in the share of ultra-processed foods to total food acquisition was associated with 1 percentage point lower contribution from beef to total food acquisition.

Restricted cubic spline regression analysis suggested a non-significant association between the share of UPF and the Shannon index after adjusting for sociodemographic factors and total amount of food acquired (**Figure 2a**). After further adjustment for the share of beef to total food acquisition, an inverse linear association was found between the share of UPF and the Shannon index (**Figure 2b**). These results were consistent with the analysis across quintiles of the share of UPF to total food acquisition (**Table 3**), which showed that there was no significant linear trend of the mean values of the Shannon index across quintiles of the share of UPF in Model 1, while the mean values of the index decreased by 16% between the first (0.94) and the fifth quintiles (0.79) in Model 2 (p for linear trend <0.05).

Figures 2c and **2d** demonstrate an inverse non-linear association between the share of beef to total food acquisition and the Shannon index after adjusting for sociodemographic variables and total amount of food acquired, and further adjustment for the share of UPF to total food acquisition, respectively. A great decline in the Shannon index was observed until the share of beef to total food acquisition reached nearly 5%. Further increases in the contribution of beef until approximately 25% were associated with a substantial decline in the Shannon index. Consistent with these results, across quintiles of the share of beef to total food acquisition, adjusted mean values of the Shannon index decreased by around 40% from the first (1.07) to the fifth quintile (0.64) in model 1, and by approximately 43% from the first (1.09) to the fifth quintile (0.62) in model 2.

Figure S1 shows a change in the order of the top six species mobilized by the first (Fig. S1a) and the fifth (Fig. S1b) quintile of the share of ultra-processed foods, with high-yield crops such as sugarcane and wheat moving from the 5th and 6th position in the first quintile to the 4th and 5th position in the fifth quintile. The top six plant species accounted for around 95% of the total amount of species mobilized both in the first and fifth quintiles (83.1% from brachiaria for both quintiles). Data from different patterns of the share of beef to total food acquisition (**Figure S2**) demonstrate that 93.8% and over 96% of the total amount of species mobilized came from only six plant species, respectively. One species (*Brachiaria*) was responsible for more than 78% and 88%, respectively of total amount of plant species required in the first and fifth quintile (Fig. S2a and Fig. S2b).

Effects of the simultaneous share of ultra-processed foods and beef on the Shannon index are presented in **Table 4**. Adjusted mean values of the diversity index decreased significantly as the share of beef to total food acquisition increased, in all scenarios of ultra-processed food acquisition (from Q1 to Q5). Similarly, the Shannon index tended to significantly decrease with an increase in the share of ultra-processed foods to total food acquisition in all scenarios of beef acquisition, except in the fifth quintile of beef ($p>0.05$). The Shannon index decreased by half (51%) moving from a scenario with the lowest share of both ultra-processed foods and beef to total food acquisition (1.22) to a scenario with the highest share of both food groups (0.60).

6.4. DISCUSSION

We described the diversity of plant species mobilized by household food acquisitions in Brazil and investigated whether different patterns of ultra-processed food and beef acquisition had an impact on this diversity. Our findings demonstrate that only six plant species (brachiaria, maize, soybean, rice, sugarcane and wheat) accounted for more than 95% of the total amount of plant species required by Brazilian household food acquisitions in 2017-18. This was reflected by a low average value of the Shannon index for the Brazilian population, indicating low diversity. As far as we know, this is the first national study to evaluate the diversity of plant species that underlie household food acquisitions, making comparison with the literature difficult. However, our findings are in line with previous studies demonstrating increasing homogeneity of global food supplies(26, 29). According to a study conducted with per capita food supply data from the Food and Agriculture Organization (FAO), national food supplies worldwide became more similar in composition over the last 50 years (1961 to 2009) particularly due to an increased supply of a number of globally important cereal and oil crops (e.g. wheat, rice, maize, soybean, sunflower, palm oil) and a decline of other cereal, oil and starchy root species such as millets, rye, sorghum, cassava, sweet potatoes(30).

The relative share of the Nova food groups and subgroups in household food acquisitions is consistent with previous analysis carried out with data from the 2017-18 HBS(31). Nevertheless, since we present values in kg-person-year instead of kcal-person-year, some differences related to the share of more energy-dense items such as processed culinary ingredients and UPF subgroups (particularly diet/light soft drinks and other non-caloric beverages which contribute to the total amount of foods acquired in kilograms but do not add any calorie) can be noted. Furthermore, our findings demonstrate an inverse linear association between the shares of UPF and of beef to total food acquisition in Brazilian households after adjusting for sociodemographic factors and total amount of food acquired, reinforcing the trend of increasing share of UPF at the expense of unprocessed/ minimally processed foods (including beef) and processed culinary ingredients in the country(31).

As indicated in our study, both household food acquisition patterns with the highest share of UPFs and of beef (Q5) were associated with lower diversity of plant species mobilized by Brazilian households when compared to household food acquisition patterns with the lowest share of these food groups (Q1). When analysing the effects of the simultaneous share of UPFs and beef on the diversity of species mobilized by household food acquisitions, we found that the Shannon index decreased by half when moving from a scenario with the lowest share of both UPFs and beef to total food acquisition to a scenario with the highest share of both food groups. Although agrobiodiversity loss has been an ongoing trend in agriculture over the past decades globally(1), these findings suggest that dietary patterns rich in UPFs and beef might be contributing to/accelerating this process in Brazil even though the effects of beef seem to be more important.

A study that evaluated associations between dietary patterns and food plant diversity in 12 countries (6 with adherence to the Mediterranean dietary pattern and 6 which follow a Western-type diet), using data from cultivated and native food plants as a proxy for the food plant diversity in dietary patterns, found that Mediterranean countries had higher average of both majorly cultivated and native food plants than countries following Western-type diet(8). According to the authors, these findings suggest that countries with adherence to the Mediterranean diet, which is mainly a plant-based diet with low amounts of red meat, support biodiversity in food plant cultivation to a greater extent when compared to the 'Western diet' countries(8).

The contribution of an increasingly prominent 'globalised diet' characterised by an abundance of branded ultra-processed food products distributed on an industrial scale to agrobiodiversity loss has been previously reported in narrative studies(7, 17). Such products, which are becoming dominant in the global food supply(32, 33), are manufactured with ingredients obtained from a handful of high-yielding plant species (e.g. maize, wheat, soy, oilseed crops)(7, 17, 18). Furthermore, these products displace the consumption of a variety of plant-sourced, unprocessed and minimally processed foods necessary for a balanced and healthy diet(34). The lack of empirical evidence demonstrating the harmful effects of these products to agrobiodiversity has been overshadowing discussion around this topic at the global level(7). It is expected that the present study can contribute to debates on this theme and to new research conducted in other contexts, particularly those with high consumption of UPFs and of animal-sourced foods from confined animals.

Findings related to the effects of beef on the diversity of plant species required by household food acquisition reinforce the inefficiencies behind the predominant cattle production systems in Brazil. According to Fortes et al(12), a few number of species (mostly high-yielding crops such as corn, soybeans, cotton, sorghum, and wheat) are used as animal feed in the Brazilian territory, with 97% of the mass mobilized coming from a single-plant species (brachiaria, the most common forage in the country). The high demand of area for pastures and monocultures directly impacts the production of other plant varieties(1, 14, 35). However, it is important to emphasise that the effects of beef on agrobiodiversity is highly dependent on the types of production systems in place. For instance, while industrial livestock production has been associated with biodiversity loss and the use of a reduced number of plant species for animal feed, regenerative livestock farming – which is based on the use of ecosystem services and natural processes such as water filtration, nutrient cycling and increased biodiversity(36) – has the potential to contribute to biodiversity conservation(37, 38). Nevertheless, this system still represents a small portion of the livestock farming in the Latin America and the Caribbean(38).

This study has several strengths. First, we used data from the most recent and nationally representative estimate of household food acquisition in Brazil to apply, for the first time, a diversity index to measure the impacts of different household food acquisition patterns on agrobiodiversity. The use of data from the national food acquisition survey has been validated as a good proxy of food consumption in the Brazilian context(39). Second, we applied a new methodology to identify the main plant and animal species that make up processed and ultra-processed foods, as well as the plant species mobilized in the production of animal source foods by taking into account the main production systems in place in the Brazilian territory(23). This is important since different types of production systems might exert different effects on agrobiodiversity. Third, we evaluated the diversity of species by considering the lowest level of taxonomic details available from (quantitative) dietary assessment. Such fact is essential for capturing the links between the diversity of species that underlie dietary patterns and ecosystems services(2). Fourth, using a consumer expenditure survey we managed to take into account the impact of all foods purchased by a household, including those that were eventually wasted. Finally, using consumer expenditure decreases the risk of underestimating ready-to-eat UPF meals.

A few limitations should also be considered in the interpretation of our findings. First, the number of species that underlie household food acquisitions could be underestimated due to the following facts: I) the most frequently ingredients used in subgroups of processed and UPFs were identified; II) estimates of the plant species mobilized in the production of animal-sourced were based on the most frequently used ingredients in Brazil. This could have misreported the real number of all species used in the production of these products(23). Second, the HBS does not capture information on the food items consumed out of home, which could undermine the number of edible species required by the Brazilian population. Though the underestimation of the number of species may have underestimated the Shannon diversity index it will unlikely affect the association between patterns of ultra-processed food and beef acquisition and the diversity of mobilized plant species. Finally, we focused our analysis in the plant species underlying household food acquisitions which does not account for the diversity of animal species mobilised by the Brazilian population. Nevertheless, this decision was based on the main objective of our study (to simulate the potential 'environmental footprint' of household food acquisitions on agricultural landscapes and homogeneity of food systems)(7, 23). Furthermore, as highlighted by Mattas et al.(8), both the definition of biodiversity and of agrobiodiversity acknowledge that the quantitative measurement of plant species and subspecies within a particular food system is a strong indicator of biodiversity.

6.5. CONCLUSION

Our findings demonstrate that food acquisition patterns rich in beef and ultra-processed foods are associated with lower diversity of species mobilised by the Brazilian population when considering the most predominant production systems in the national territory. Further research is needed to test associations between dietary patterns rich in other animal-sourced foods such as poultry and pork, and also taking into account other types of production systems (e.g. regenerative livestock farming).

6.6. REFERENCES

1. FAO. The State of the World’s Biodiversity for Food and Agriculture. Rome: FAO Commission on Genetic Resources for Food and Agriculture Assessments; 2019.
2. Bioversity International. Mainstreaming Agrobiodiversity in Sustainable Food Systems: Scientific Foundations for an Agrobiodiversity Index. Rome: Bioversity International; 2017.
3. Antonelli A, Fry C, Smith RJ, Simmonds MSJ, Kersey PJ, Pritchard HW, et al. State of the World's Plants and Fungi 2020. Research report. Royal Botanic Gardens, Kew; 2020 2020-07-30.
4. FAO. The Commission on Genetic Resources for Food and Agriculture (CGRFA) Second Report on the State of the World’s Plant Genetic Resources for Food and Agriculture (PGRFA). Rome, Italy: FAO; 2012.
5. FAOSTAT Food Balances [Internet]. 2010 [cited 22nd June 2022]. Available from: http://www.fao.org/faostat/
6. Krug AS, E BMD, Van Tassel DL, Warschefsky EJ. The next era of crop domestication starts now. Proceedings of the National Academy of Sciences of the United States of America. 2023;120(14):e2205769120.
7. Leite FHM, Khandpur N, Andrade GC, Anastasiou K, Baker P, Lawrence M, et al. Ultra-processed foods should be central to global food systems dialogue and action on biodiversity. BMJ Global Health. 2022;7(3):e008269.
8. Mattas K, Raptou E, Alayidi A, Yener G, Baourakis G. Assessing the Interlinkage between Biodiversity and Diet through the Mediterranean Diet Case. Advances in nutrition (Bethesda, Md). 2023;14(3):570-82.
9. Brazil. Dietary Guidelines for the Brazilian Population. In: Department. MoHoBSoHCPHC, editor. íli ed. Brasília: Ministry of Health Brazil; 2015. p. 150 p.
10. Fanzo J, Miachon L. Harnessing the connectivity of climate change, food systems and diets: Taking action to improve human and planetary health*. Anthropocene. 2023;42:20.
11. Herrero M, Mason-D’Croz D, Thornton PK, Fanzo J, Rushton J, Godde C, et al. Livestock and Sustainable Food Systems: Status, Trends, and Priority Actions. In: von Braun J, Afsana K, Fresco LO, Hassan MHA, editors. Science and Innovations for Food Systems Transformation. Cham: Springer International Publishing; 2023. p. 375-99.
12. Fortes MF, Leite FHM, Garzillo JMF, Monteiro CA. Analysis of the Impact of the Meat Supply Chain on the Brazilian Agri-Food System. SSRN. 2020.
13. Eshel G, Shepon A, Makov T, Milo R. Partitioning United States' feed consumption among livestock categories for improved environmental cost assessments. J Agric Sci. 2015;153(3):432-45.
14. Benton TG, Bieg C, Harwatt H, Pudasaini R, Wellesley L. Food system impacts on biodiversity loss. Three levers for food system transformation in support of nature. London: Chatham house; 2021.
15. Monteiro CA, Cannon G, Levy RB, Moubarac J, Louzada MLC, Rauber F, et al. Ultra-processed foods: what they are and how to identify them. Public Health Nutr. 2019;22(5):936-41.
16. Marron-Ponce JA, Sanchez-Pimienta TG, Rodriguez-Ramirez S, Batis C, Cediel G. Ultra-processed foods consumption reduces dietary diversity and micronutrient intake in the Mexican population. Journal of human nutrition and dietetics : the official journal of the British Dietetic Association. 2023;36(1):241-51.
17. Fardet A, Rock E. Ultra-Processed Foods and Food System Sustainability: What are the Links? Sustainability. 2020;12(6280):1-26.
18. Anastasiou K, Baker P, Hadjikakou M, Hendrie GA, Lawrence M. A conceptual framework for understanding the environmental impacts of ultra-processed foods and implications for sustainable food systems. J Clean Prod. 2022;368:16.
19. Rist S, Bonanomi EB, Giger M, Hett C, Scharrer B, Jacobi J, et al. Variety is the source of life: Agrobiodiversity benefits, challenges, and needs. 2020.

20. Clark M, Springmann M, Rayner M, Scarborough P, Hill J, Tilman D, et al. Estimating the environmental impacts of 57,000 food products. Proceedings of the National Academy of Sciences of the United States of America. 2022;119(33):e2120584119.
21. Instituto Brasileiro de Geografia e Estatística (IBGE). Pesquisa de Orçamentos Familiares 2017-2018: avaliação nutricional da disponibilidade domiciliar de alimentos no Brasil. In: IBGE, editor. Rio de Janeiro2020.
22. Monteiro CA. Nutrition and health. The issue is not food, nor nutrients, so much as processing. Public Health Nutr. 2009;12(5):729-31.
23. Leite FHM, Andrade GC, Steele EM, Garzillo JMF, Levy RB, Fanzo J, et al. Methodology for determining the agrobiodiversity that underlies human diets: an application using Brazilian food purchase data. In preparation.
24. Shannon CE. A mathematical theory of communication. The Bell System Technical Journal. 1948;27(3):379-423.
25. Hanley-Cook GT, Daly AJ. Food biodiversity: Quantifying the unquantifiable in human diets. 2023;63(25):7837-51.
26. Remans R, Wood SA, Saha N, Anderman TL, DeFries RS. Measuring nutritional diversity of national food supplies. Global Food Secur. 2014;3(3):174-82.
27. Béné C, Fanzo J, Prager SD, Achicanoy HA, Mapes BR, Alvarez Toro P, et al. Global drivers of food system (un)sustainability: A multi-country correlation analysis. PLoS ONE. 2020;15(4).
28. Gustafson D, Gutman A, Leet W, Drewnowski A, Fanzo J, Ingram J. Seven Food System Metrics of Sustainable Nutrition Security. Sustainability. 2016;8(3):196.
29. Chaudhary A, Gustafson D, Mathys A. Multi-indicator sustainability assessment of global food systems. Nature Communications. 2018;9.
30. Khoury CK, Bjorkman AD, Dempewolf H, Ramirez-Villegas J, Guarino L, Jarvis A, et al. Increasing homogeneity in global food supplies and the implications for food security. Proceedings of the National Academy of Sciences of the United States of America. 2014;111(11):4001-6.
31. Levy RB, Andrade GC. Three decades of household food availability according to NOVA - Brazil, 1987-2018. 2022;56:75.
32. Monteiro CA, Moubarac JC, Cannon G, Ng SW, Popkin B. Ultra-processed products are becoming dominant in the global food system. Obesity reviews : an official journal of the International Association for the Study of Obesity. 2013;14 Suppl 2:21-8.
33. Baker P, Machado P, Santos T, Sievert K, Backholer K. Ultra-processed foods and the nutrition transition: Global, regional and national trends, food systems transformations and political economy drivers. 2020;21(12):e13126.
34. Monteiro CA, Cannon G, Lawrence M, Louzada MLC, Machado PP. Ultra-processed foods, diet quality, and health using the NOVA classification system. Rome FAO; 2019.
35. FAO and UNEP. The State of the World's Forests 2020. Forests, biodiversity and people. Rome.. 2020.
36. FAO. Regenerative livestock farming. Ecuador: FAO; 2023.
37. Griscom BW, Adams J, Ellis PW, Houghton RA, Lomax G, Miteva DA, et al. Natural climate solutions. Proceedings of the National Academy of Sciences. 2017;114(44):11645-50.
38. Abramovay R, Matte A, Sanseverino EC, Ritt AL, Galiano MW. Pecuária regenerativa na América Latina e no Caribe. São Paulo: Cátedra Josué de Castro da Faculdade de Saúde Pública da Universidade de São Paulo; 2023.
39. Louzada MLdC, Levy RB, Martins APB, Claro RM, Steele EM, Verly Jr E, et al. Validating the usage of household food acquisition surveys to assess the consumption of ultra-processed foods: Evidence from Brazil. Food Policy. 2017;72:112-20.

6.7. TABLES AND FIGURES

Table 1. Shannon diversity index relative to the diversity of plant species mobilized by annual household food acquisitions according to sociodemographic variables. Brazilian household strata, July 2017-July 2018 (n=575).

Variables	Sample distribution (%)	Shannon entropy diversity index[∫] Mean (95% CI)	
		Crude	Adjusted[§]
Per capita income[§] (quintiles)			
Q1	20	0.79 (0.76; 0.82)	0.82 (0.78; 0.85)
Q2	20	0.87 (0.83; 0.90)	0.89 (0.86; 0.92)
Q3	20	0.86 (0.83; 0.90)	0.86 (0.83; 0.90)
Q4	20	0.85 (0.80; 0.89)	0.84 (0.79; 0.88)
Q5	20	0.91 (0.88; 0.94)[*]	0.87 (0.84; 0.91)
Residential area			
Urban	86.2	0.85 (0.83; 0.87)	0.84 (0.83; 0.86)
Rural	13.8	0.89 (0.85; 0.94)	0.95 (0.90; 0.99)[*]
Macroregion			
North	7.3	0.66 (0.63; 0.70)[a]	0.69 (0.65; 0.73)[a]
Northeast	25.9	0.84 (0.81; 0.86)[b]	0.83 (0.80; 0.86)[c]
Southeast	43.6	0.92 (0.90; 0.95)[c]	0.93 (0.90; 0.96)[d]
South	15.4	0.84 (0.80; 0.88)[b]	0.82 (0.79; 0.86)[bc]
Midwest	7.8	0.75 (0.70; 0.79)[d]	0.74 (0.70; 0.79)[ab]
Total	**100**	**0.86 (0.84; 0.87)**	

CI: Confidence interval

∫ This index considers both species richness and equality of distribution among species.

§ Adjusted for income, area, region and total amount of food acquired (in kilograms).

* p<0.05 for dichotomous variable (residential area) and p for linear trend <0.05 for ordinal variables (per capita income).

a,b,c,d p<0.05 in the Bonferroni test for two-by-two comparisons of macroregions, when macroregions do not share the same superscript letter.

§ Mean (Min-max range) per capita household aggregates income (in reais): Q1 (R$ 776.3; R$ 298.7 - R$ 1,064.5), Q2 (R$ 1,260.1; R$ 1,064.5 – R$ 1,430.4), Q3 (R$ 1,678.0; R$ 1,430.4 – R$1,894.0), Q4 (R$ 2,060.6; R$ 1,898.6 – R$ 2,246.9), Q5 (R$ 3,614.1; R$ 2,247.8 – R$ 11,522.8).

Table 2. Annual household food acquisitions according to sociodemographic variables. Brazilian household strata, July 2017-July 2018 (n=575).

Variables	Total food acquisitions (kg-person-year)	Ultra-processed food (UPF) acquisitions (kg-person-year)	Share of UPF (%) in total food acquisitions	Beef acquisitions[∫] (kg-person-year)	Share of beef (%) in total food acquisitions
	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)
Per capita income[§] (quintiles)					
Q1	222.6 (210.7; 234.4)	43.8 (38.0; 49.5)	18.6 (16.8; 20.4)	13.5 (12.5; 14.5)	6.3 (5.9; 6.7)
Q2	252.4 (236.2; 268.6)	68.2 (55.5; 80.9)	25.4 (22.5; 28.3)	12.7 (11.8; 13.5)	5.3 (4.9; 5.7)
Q3	257.1 (240.2; 273.9)	59.5 (53.8; 65.2)	23.1 (21.9; 24.2)	13.4 (12.4; 14.5)	5.3 (5.0; 5.6)
Q4	269.4 (252.9; 285.9)	72.1 (64.8; 79.3)	26.7 (25.1; 28.3)	14.4 (12.8; 15.9)	5.4 (4.9; 5.9)
Q5	317.8 (297.3; 338.3)*	96.9 (87.6; 106.2)*	30.2 (28.2; 32.1)*	14.7 (13.0; 16.5)	4.6 (4.2; 5.1)*
Residential area					
Urban	265.7 (256.9; 274.6)	73.0 (68.2; 77.8)	26.5 (25.4; 27.5)	13.9 (13.3; 14.6)	5.4 (5.2; 5.6)
Rural	250.5 (236.5; 274.6)	35.8 (31.4; 40.3)*	13.8 (12.4; 15.1)*	12.6 (11.7; 13.5)*	5.4 (5.0; 5.9)
Macroregion					
North	214.4 (197.0; 231.8)[b]	44.4 (36.5; 52.3)[a]	19.5 (17.2; 21.7)[a]	16.9 (15.0; 18.7)[b]	7.9 (7.5; 8.4)[b]
Northeast	262.8 (250.1; 275.6)[a]	75.1 (63.7; 86.4)[c]	25.9 (23.1; 28.7)[b]	13.3 (12.6; 14.1)[a]	5.4 (5.0; 5.7)[a]
Southeast	259.6 (245.6; 273.7)[a]	67.7 (61.4; 74.0)[bc]	25.7 (24.3; 27.0)[b]	11.9 (11.0; 12.8)[a]	4.6 (4.4; 4.9)[c]
South	303.2 (284.1; 322.4)[c]	74.7 (68.2; 81.2)[c]	24.8 (23.6; 25.9)[b]	15.9 (14.9; 16.9)[b]	5.5 (5.1; 5.8)[a]
Midwest	255.8 (235.8; 275.9)[a]	53.3 (45.3; 61.3)[ab]	20.4 (18.4; 22.4)[a]	18.1 (15.0; 21.1)[b]	7.2 (6.3; 8.1)[b]
Total	**263.6 (255.7; 271.5)**	**67.9 (63.5; 72.2)**	**24.7 (23.7; 25.8)**	**13.7 (13.2; 14.3)**	**5.4 (5.2; 5.6)**

CI: Confidence interval; UPF: ultra-processed foods.
*p<0.05 for dichotomous variable (residential area) and p for linear trend <0.05 for ordinal variables (per capita income).
a,b,c,d p<0.05 in the Bonferroni test for two-by-two comparisons of macroregions, when macroregions do not share the same superscript letter.
∫ The total amount of beef (in kilograms) included: total amount (in kilograms) from unprocessed/minimally processed beef (group 1); beef offal (group 1); cured, smoked or pickled beef (group 3); reconstituted beef products and ready-to-eat dishes made of beef (group 4).
§ Mean (Min.-max. range) per capita household aggregates income (in Brazilian Real): Q1 (R$ 776.3; R$ 298.7 - R$ 1,064.5), Q2 (R$ 1,260.1; R$ 1,064.5 – R$ 1,430.4), Q3 (R$ 1,678.0; R$ 1,436.4 – R$1,894.0), Q4 (R$ 2,060.6; R$ 1,898.6 – R$ 2,246.9), Q5 (R$ 3,614.1; R$ 2,247.8 – R$ 11,522.8).

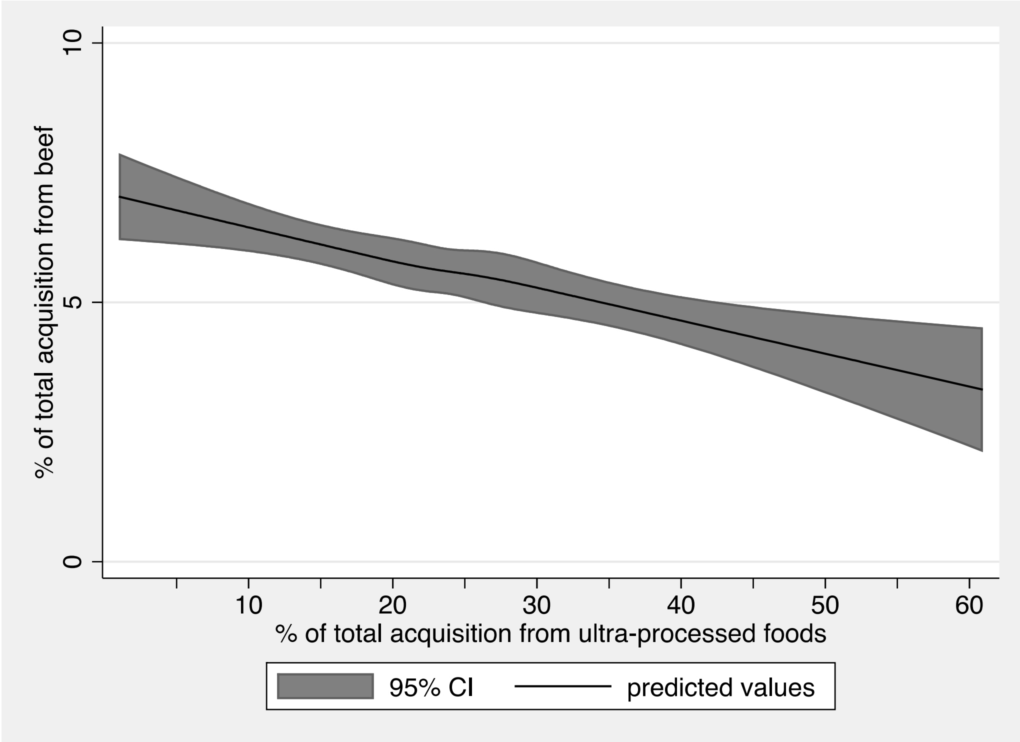


Figure 1. The % of total food acquisitions from beef regressed on the % of total food acquisitions from ultra-processed foods evaluated by restricted cubic splines. Brazilian household strata (National Household Budget Survey 2017-18) (N=575).

Coefficient for linear term= -0.160 (95% CI -0.275 to -0.046). There was little evidence of non-linearity in the restricted cubic spline model (Wald test for linear term p=0.006; Wald test for all non-linear terms p=0.06). The values corresponding to the 20th, 40th, 60th, 80th centiles for percentage of total acquisition from ultra-processed foods (knots) were 17.7; 22.5; 25.8; 31.0, respectively.

Regression model adjusted for area, region, income and total amount of food acquired (in kilograms).

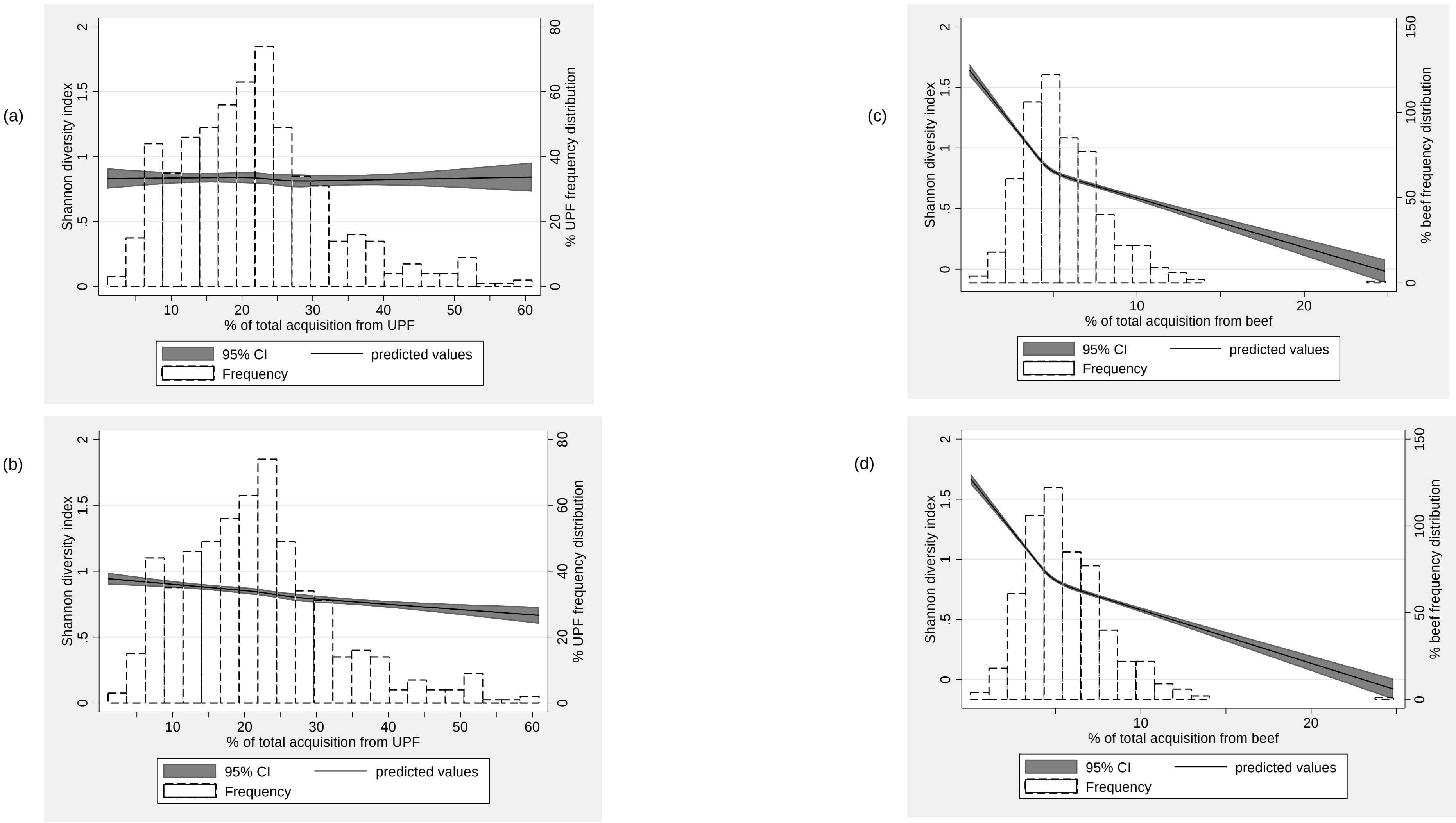


Figure 2. Shannon diversity index (H) regressed on the total household food acquisition share of (a,b) ultra-processed foods and (c,d) beef evaluated by restrict cubic splines. Brazilian household strata (National Household Budget Survey 2017-18) (N=575).

(a) Coefficient for linear term= 0.005 (95% CI -.001 to 0.010). There was little evidence of linearity in the restricted cubic spline model (Wald test for linear term p= 0.102; Wald test for all non-linear terms p= 0.047); (b) Coefficient for linear term= -0.008 (95% CI -0.012 to -0.004). There was little evidence of non-linearity in the restricted cubic spline model (Wald test for linear term p= 0<0.001; Wald test for all non-linear terms p= 0.1036); (c) Coefficient for linear term= -0.157 (95% CI -0.183 to -0.131). There was little evidence of linearity in the restricted cubic spline model (Wald test for linear term p<0.001; Wald test for all non-linear terms p<0.001); (d) Coefficient for linear term= -0.169 (95% CI -0.192 to -0.146). There was little evidence of linearity in the restricted cubic spline model (Wald test for linear term p<0.001; Wald test for all non-linear terms p<0.001). The values corresponding to the 20th, 40th, 60th, 80th centiles for percentage of total acquisition from ultra-processed foods (knots) were 17.7 22.5 25.8 31.0, respectively. The values corresponding to the 20th, 40th, 60th, 80th centiles for percentage of total acquisition from beef (knots) were and 3.8 4.6 5.4 6.9, respectively. Model 1 (a,c) adjusted for area, region, income, total amount of food acquired (in kilograms). Model 2 (b,d) adjusted for area, region, income, total amount of food acquired (in kilograms) and other exposure variable (continuous). Histograms of the distribution of UPF and of beef are plotted in the background. UPF: ultra-processed food. CI: Confidence interval.

Table 3. Shannon diversity index relative to the diversity of plant species mobilized through household food acquisitions in Brazil by the share of selected food groups (UPFs and beef) in total food acquisition. Brazilian household strata, July 2017-July 2018 (n=575).

Quintiles of the share of food groups in total household food acquisition (kg-person-year)	Shannon diversity index Mean (95% CI)		
	Crude	**Model 1**	**Model 2**
Ultra-processed foods§			
Q1	0.84 (0.80; 0.88)	0.88 (0.84; 0.92)	0.94 (0.92; 0.96)
Q2	0.82 (0.79; 0.85)	0.84 (0.82; 0.86)	0.86 (0.85; 0.87)
Q3	0.87 (0.83; 0.91)	0.87 (0.84; 0.90)	0.86 (0.84; 0.87)
Q4	0.86 (0.82; 0.90)	0.84 (0.79; 0.88)	0.83 (0.81; 0.84)
Q5	0.89 (0.86; 0.91)*	0.85 (0.82; 0.89)	0.79 (0.78; 0.81)*
Beef∫			
Q1	1.07 (1.04; 1.10)	1.07 (1.04; 1.10)	1.09 (1.07; 1.12)
Q2	0.93 (0.92; 0.95)	0.93 (0.91; 0.94)	0.94 (0.93; 0.95)
Q3	0.86 (0.85; 0.88)	0.86 (0.85; 0.88)	0.86 (0.85; 0.87)
Q4	0.77 (0.75; 0.78)	0.77 (0.75; 0.78)	0.76 (0.75; 0.77)
Q5	0.64 (0.62; 0.65)*	0.64 (0.63; 0.66)*	0.62 (0.60; 0.64)*

UPF: ultra-processed foods. CI: Confidence interval.
Model 1: adjusted for area, region, income, total amount of food acquired (in kilograms)
Model 2: adjusted for area, region, income, total amount of food acquired (in kilograms), and other exposure variable (% share of beef in the UPF model; % share of UPF in the beef model)
*p<0,05 for linear trend.
§ Mean (Min.-max. range) share of ultra-processed foods per quintile: Q1 (12.3%; 1.0% - 17.7%), Q2 (20.6%; 17.8% - 22.5%), Q3 (24.1%; 22.5% - 25.8%), Q4 (28.2%; 25.8% - 31.0%), Q5 (38.6%; 31.0% - 60.9%).
∫ Mean (Min.-max. range) share of beef per quintile: Q1 (3.1%; 0.0% - 3.8%), Q2 (4.2%; 3.8% - 4.6%), Q3 (5.0%; 4.6% - 5.4%), Q4 (6.1%; 5.4% - 6.9%), Q5 (8.6%; 6.9% - 24.7%).

Table 4. Shannon diversity index relative to the diversity of plant species mobilized by annual household food acquisitions according to the share of ultra-processed foods and beef. Brazilian household strata, July 2017-July 2018 (n=575).

Quintiles of the share of UPF[§] (kg-person-year)	Quintiles of the share of beef[ʃ]				
	Q1* Mean (95% CI)	Q2* Mean (95% CI)	Q3* Mean (95% CI)	Q4* Mean (95% CI)	Q5* Mean (95% CI)
Q1*	1.22 (1.16; 1,29)	1.00 (0.97; 1.03)	0.93 (0.91; 0.96)	0.80 (0.77; 0.83)	0.64 (0.61; 0.67)[b]
Q2*	1.06 (0.91; 1.21)	0.95 (0.91; 0.98)	0.89 (0.87; 0.91)	0.77 (0.75; 0.79)	0.68 (0.66; 0.70)[b]
Q3*	1.10 (1.04; 1.14)	0.96 (0.94; 0.98)	0.85 (0.83; 0.88)	0.78 (0.76; 0.80)	0.64 (0.61; 0.67)[b]
Q4*	1.05 (1.00; 1.10)	0.91 (0.89; 0.93)	0.83 (0.80; 0.85)	0.75 (0.72; 0.77)	0.64 (0.59; 0.70)[b]
Q5*	0.99 (0.95; 1.02)[a]	0.89 (0.86; 0.91)[a]	0.80 (0.77; 0.83)[a]	0.70 (0.67; 0.73)[a]	0.60 (0.55; 0.65)[b]

UPF: ultra-processed foods. Wald test for interaction p<0.001.
*Adjusted for area, region, income and total amount of food acquired (in kilograms).
[a,b] p<0,05 for linear trend
[§] Mean (Min.-max. range) share of ultra-processed foods per quintile: Q1 (12.3%; 1.0% - 17.7%), Q2 (20.6%; 17.8% - 22.5%), Q3 (24.1%; 22.5% - 25.8%), Q4 (28.2%; 25.8% - 31.0%), Q5 (38.6%; 31.0% - 60.9%).
[ʃ] Mean (Min.-max. range) share of beef per quintile: Q1 (3.1%; 0.0% - 3.8%), Q2 (4.2%; 3.8% - 4.6%), Q3 (5.0%; 4.6% - 5.4%), Q4 (6.1%; 5.4% - 6.9%), Q5 (8.6%; 6.9% - 24.7%).

6.8. SUPPLEMENTARY MATERIAL

APPENDIX 1: NOVA food groups and subgroups

NOVA group	Definition	Subgroups
1) Unprocessed or minimally processed foods	Unprocessed: edible parts of plants (fruits, seeds, leaves, stems, roots, tubers) or of animals (muscle, offals, eggs, milk), and also fungi, algae and water, after separation from nature. Minimally processed: unprocessed foods altered by industrial processes such as removal of inedible or unwanted parts, drying, crushing, grinding, fractioning, roasting, boiling, pasteurisation, refrigeration, freezing, placing in containers, vacuum packaging, non-alcoholic fermentation, and other methods that do not add salt, sugar, oils or fats or other food substances to the original food. The main aim of these processes is to extend the life of unprocessed foods, enabling their storage for longer use, and, often, to make their preparation easier or more diverse. Infrequently, minimally processed foods contain additives that prolong product duration, protect original properties or prevent proliferation of microorganisms.	(n=20) fruits; milk; rice; vegetables; beef; poultry; roots and tubers; beans and other pulses; flours (wheat, cassava, maize, other); eggs; pasta; pig meat; maize, oat, other cereals; fish; coffee and tea; seafood; spices and herbs; nuts and seeds; other meats (e.g. sheep, goat); offal.
2) Processed culinary ingredients	Substances obtained directly from group 1 foods or from nature by industrial processes such as pressing, centrifuging, refining, extracting or mining. Their use is in the preparation, seasoning and cooking of group 1 foods. These products may contain additives that prolong product duration, protect original properties or prevent proliferation of microorganisms.	(n=8) table sugar; other sugars (e.g. honey); starches; salt; animal fat (e.g. butter, lard, cream); vegetable fat/oil; other culinary ingredients; processed plant-based milk alternatives (soy, coconut, oat)
3) Processed foods	Products made by adding salt, oil, sugar or other group 2 ingredients to group 1 foods, using preservation methods such as canning and bottling, and, in the case of breads and cheeses, using non-alcoholic fermentation. Processes and ingredients here aim to increase the durability of group 1 foods and make them more enjoyable by modifying or enhancing their sensory qualities. These products may contain additives that prolong product duration, protect original properties or prevent proliferation of microorganisms.	(n=18) smoked beef; salt-cured/dried beef; canned beef; reconstituted beef; processed poultry meat; smoked pork; salt-cured/dried pork; reconstituted/canned pork; smoked fish and seafood; salt-cured/dried fish and seafood; canned fish and seafood; canned vegetables; fruit jam; processed nuts and seeds; processed bread; processed cheese; beer; wine

4) Ultra-processed foods	Formulations of ingredients, mostly of exclusive industrial use, that result from a series of industrial processes (hence 'ultra-processed'), many requiring sophisticated equipment and technology. Processes enabling the manufacture of ultra-processed foods include the fractioning of whole foods into substances, chemical modifications of these substances, assembly of unmodified and modified food substances using industrial techniques such as extrusion, moulding and pre-frying, frequent application of additives whose function is to make the final product palatable or hyper-palatable ('cosmetic additives'), and sophisticated packaging, usually with synthetic materials. Ingredients often include sugar, oils and fats, and salt, generally in combination; substances that are sources of energy and nutrients but of no or rare culinary use such as high fructose corn syrup, hydrogenated or interesterified oils, and protein isolates; cosmetic additives such as flavours, flavour enhancers, colours, emulsifiers, sweeteners, thickeners, and anti-foaming, bulking, carbonating, foaming, gelling, and glazing agents; and additives that prolong product duration, protect original properties or prevent proliferation of microorganisms. Processes and ingredients used to manufacture ultra-processed foods are designed to create highly profitable products (low cost ingredients, long shelf-life, emphatic branding), convenient (ready-to-consume) hyper-palatable snacked products liable to displace all other NOVA food groups, notably group 1 foods.	(n=82) sweet biscuits (regular/light/diet); salty snacks (regular/light); margarine and vegetable spreads (regular/light); baked goods (regular/light/diet); mass-produced packaged bread (regular/light/diet); soft drinks (regular/diet); chocolates (regular/light/diet); artificial juices and other sweetened beverages (regular/light); dairy drinks (regular/light/diet); ice cream (regular/diet); sauces (regular/light); breakfast cereals; cereal bars (regular/light/diet); chocolate milk (regular/light/diet); fruit jam (regular/diet); candies; syrups and toppings; gum (regular/light); powdered dessert (regular/diet); puddings, flans, and mousses (regular/diet); creams; confectionery; caramelized milk (regular/diet); peanut/nut candy (regular/diet); caramel; other sweets; ultra-processed cheese (regular/light); double cream (regular/light); condensed milk (regular/light/diet); ready-to-eat pasta; instant noodles (regular/light); ready-to-eat soups; ready-to-eat pizzas; sandwiches and wraps; fried and baked savoury meals; pies and pancakes; rice-based ready-to-eat meals; potato-based ready-to-eat meals; flour-based ready-to-eat meals; corn-based ready-to-eat meals; plant-based ready-to-eat meals; pork-based ready-to-eat meals; beef-based ready-to-eat meals; poultry-based ready-to-eat meals; fish-based ready-to-eat meals; ultra-processed beef meat; ultra-processed pork meat; ultra-processed poultry meat; ultra-processed fish and seafood meat; spirts; crackers; soy-based beverages; seasoning tablets/ready-to-eat condiments.

Table S1. Distribution (%) of annual household food acquisitions according to the Nova groups and subgroups. Brazilian household strata, July 2017-July 2018 (n=575).

Food group	Mean total amount Absolute (kg-person-year)	Relative (% of total acquisitions)
Unprocessed or minimally processed foods	**154.7**	**59.5**
Fruits	28.6	10.7
Milk	26.2	9.9
Rice	19.7	8.0
Vegetables	16.3	6.2
Beef[a]	12.7	5.0
Poultry	12.6	4.9
Roots and tubers	7.8	2.9
Beans and other pulses	6.3	2.5
Flours (wheat, cassava, maize, others)	5.8	2.2
Eggs	3.4	1.3
Pasta	3.1	1.2
Pig meat	2.6	1.0
Maize, oat and other cereals	2.2	0.9
Fish	2.2	0.9
Other[a,b]	5.3	2.0
Processed culinary ingredients	**19.1**	**7.4**
Table sugar	10.8	4.2
Vegetable oils	5.4	2.1
Starches	0.8	0.3
Animal fats (butter, lard, cream)	0.5	0.2
Other[c]	1.6	0.6
Processed foods	**21.9**	**8.4**
Fresh bread	9.9	3.9
Fermented alcoholic beverages	6.8	2.5
Cheese	2.0	0.7
Cured, smoked or pickled meat[a]	1.0	0.4
Other[d]	2.3	0.8
Ultra-processed foods	**67.9**	**24.7**
Soft drinks	38.0	13.4
Reconstituted meat products[a]	4.7	1.8
Non-carbonated sugar sweetened beverages	3.0	1.1
Milk-based drinks	3.0	1.1
Ultra-processed breads	2.2	0.8
Sweet biscuits	2.1	0.8
Ready-to-eat sauces	2.1	0.8
Cakes and other sweet bakery goods	1.9	0.7
Chips, crackers and other salty snacks	1.9	0.7
Ready-to-eat dough (pizza, lasagna)	1.6	0.6
Ready-to-eat dishes[a]	1.5	0.6
Confectionery	1.3	0.5
Margarine	1.2	0.5
Chocolate	1.2	0.4
Ice cream	0.9	0.3
Other[e]	1.2	0.5
Total	**263.6**	**100.0**

[a] Categories that include food items from beef.
[b] Coffee and tea, seafood, spices and herbs, nuts and seeds, other meats (e.g. sheep, goat), offal.
[c] Honey, cane syrup, salt, plant-based milk alternatives (soy, coconut, oat).
[d] Fruits, vegetables or pulses preserved in oil, salt or sugar; vinegar; cured, smoked or pickled fish.
[e] Breakfast cereals, seasoning mixes/tablets, ultra-processed cheeses, distilled beverages.

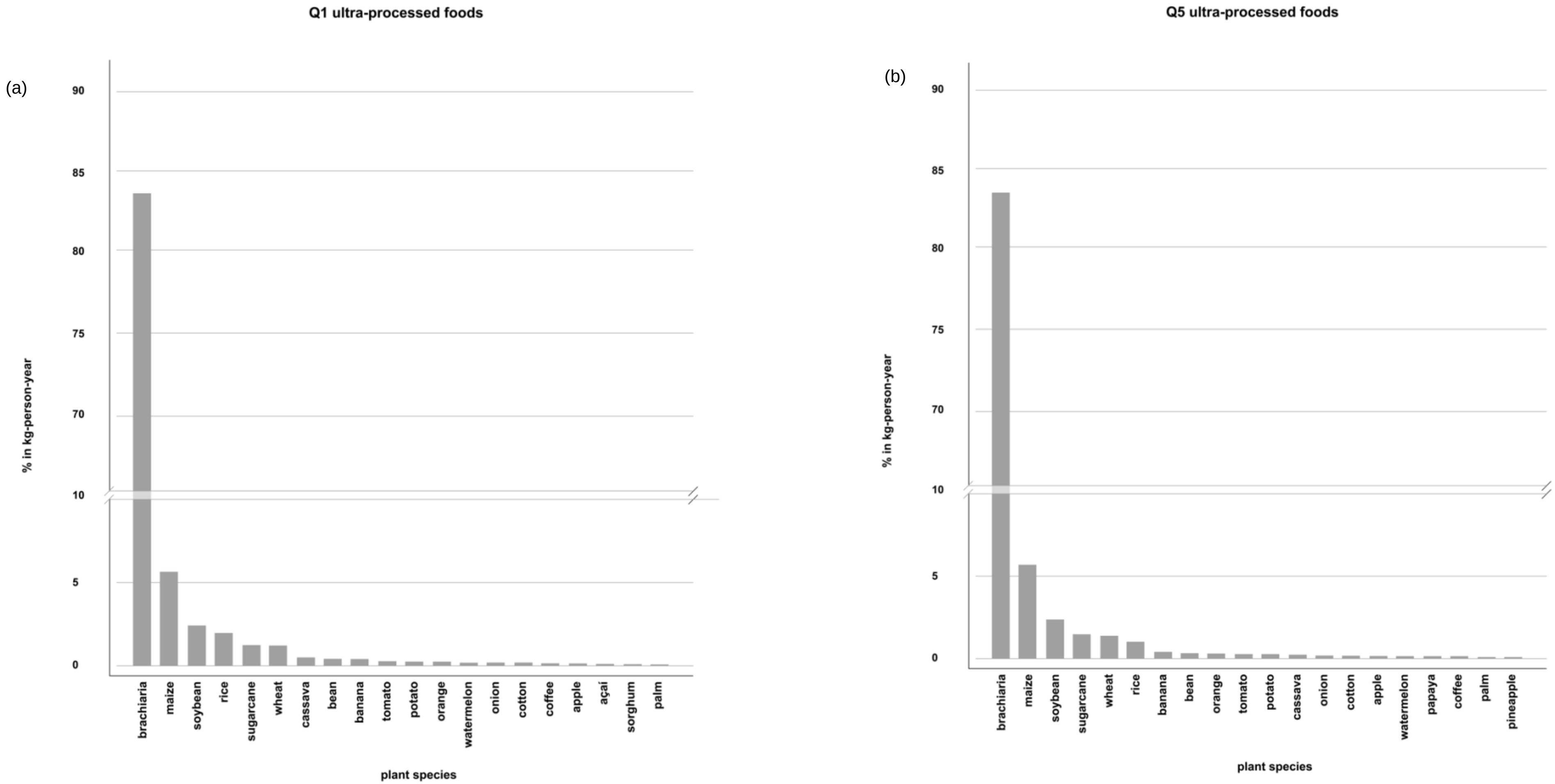
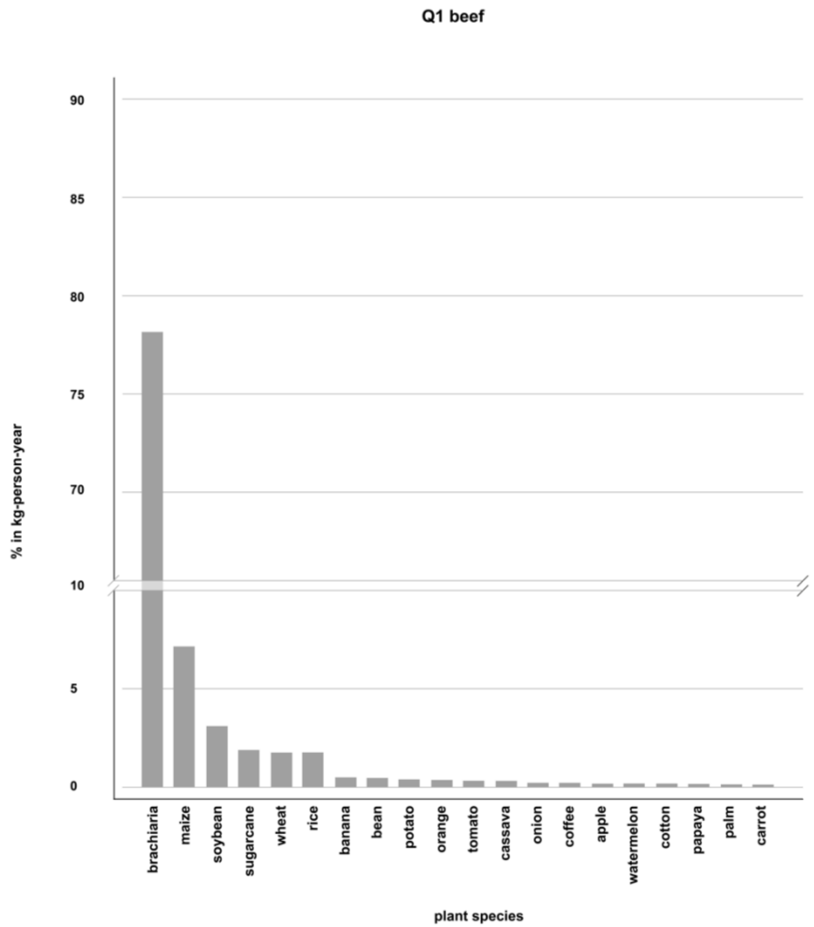


Figure S1. Distribution (%) of the total amount of plant species in kilograms mobilized by annual household food acquisitions (top 20 species) according to the share of ultra-processed foods (Q1-low; Q5-high). Brazilian household strata, July 2017-July 2018 (n=575).

(a)



(b)

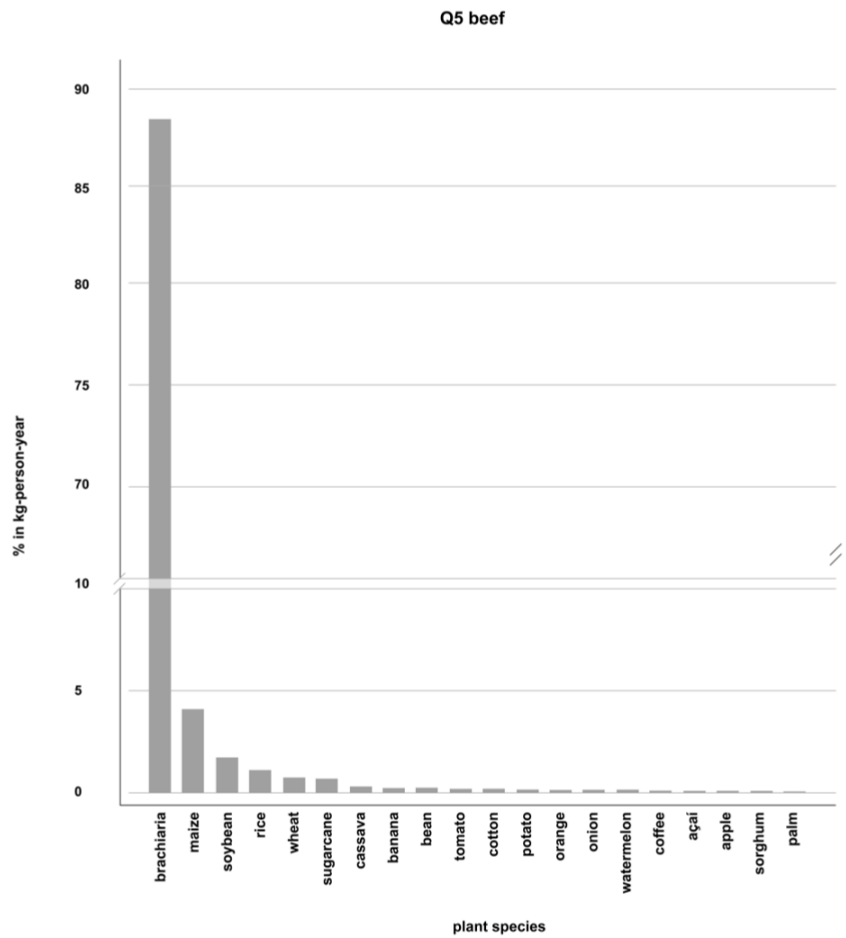


Figure S2. Distribution (%) of the total amount of plant species in kilograms mobilized by annual household food acquisitions (top 20 species) according to the share of beef (Q1-low; Q5-high). Brazilian household strata, July 2017-July 2018 (n=575).

7. CONSIDERAÇÕES FINAIS

O presente estudo apresenta metodologia inédita para a determinação da agrobiodiversidade mobilizada pela dieta, bem como resultados robustos, e também inéditos, sobre padrões de consumo de alimentos ultraprocessados e da carne bovina e sua influência sobre a agrobiodiversidade no Brasil, utilizando dados da Pesquisa de Orçamentos Familiares mais recente (2017-18).

O comentário elaborado como parte desta tese (manuscrito 1) marcou o início do debate sobre a contribuição das dietas globais, com foco principalmente no papel dos alimentos ultraprocessados para a perda de agrobiodiversidade, além de ter destacado a completa ausência de tais discussões nas agendas globais de sistemas alimentares, convenções de biodiversidade e conferências sobre alterações climáticas realizadas no ano de 2021. Conforme apontado neste manuscrito, as taxas sem precedentes da perda da agrobiodiversidade reforçam a necessidade de uma rápida transição de padrões alimentares ricos em alimentos ultraprocessados e produtos de origem animal para aqueles ricos em alimentos de origem vegetal, *in natura* e minimamente processados e consumidos em grande variedade. A ausência deste debate nas agendas globais sobre sistemas alimentares, nutrição e mudanças climáticas é estarrecedora e precisa ser superada.

Já a abordagem metodológica desenvolvida com o intuito de determinar a agrobiodiversidade subjacente às dietas humanas descreve, pela primeira vez, os passos necessários para a identificação de espécies animais e vegetais que compõem alimentos processados e ultraprocessados, além de estimar as espécies vegetais utilizadas como pastagens e/ou rações no ciclo de vida de animais e dos respectivos produtos de origem animal adquiridos por domicílios brasileiros. Esta abordagem metodológica poderá ser replicada em diferentes contextos e comparada, a fim de fornecer uma visão mais ampliada sobre os efeitos de padrões alimentares com potencial de conservação ou deterioração da agrobiodiversidade. A aplicação desta metodologia em dados da Pesquisa de Orçamentos Familiares revelou que, apesar de 225 espécies vegetais terem sido mobilizadas por domicílios brasileiros em 2017-18, uma única espécie de pastagem foi responsável por mais de 80% do total de espécies mobilizadas em kg-pessoa-ano por meio da aquisição de carne e leite de bovinos, derivados de leite processados e alimentos ultraprocessados contendo carne bovina ou leite e derivados em sua composição. Tal fato apontou para uma baixa diversidade de espécies vegetais demandadas no cenário nacional, porém métricas que levassem em conta tanto o número quanto a distribuição de espécies na amostra estudada precisariam ser utilizadas a fim de validar tal hipótese de forma mais apropriada (conforme descrito abaixo).

As principais hipóteses desta tese – a saber: 1) que as aquisições domiciliares de alimentos no Brasil demandavam uma baixa diversidade de espécies (estimada a partir do Índice de Shannon) e 2) que padrões de alimentos ricos em alimentos ultraprocessados e carne bovina estavam associados a uma menor agrobiodiversidade demandada – foram confirmadas. Nossos achados demonstraram que apenas seis espécies vegetais (braquiária, milho, soja, arroz, cana-de-açúcar e trigo) foram responsáveis por mais de 95% do total de espécies mobilizadas por aquisições domiciliares de alimentos no Brasil em 2017-18. Tal monotonia foi refletida no baixo valor do Índice de Shannon para a população brasileira, indicando baixa diversidade. Além disso, o valor do Índice de Shannon foi reduzido pela metade, passando de um cenário com baixa participação de carne bovina e de alimentos ultraprocessados no total adquirido para um cenário com alta participação de ambos os grupos. Tal resultado conversa com resultados de estudos anteriores realizados com dados de disponibilidade nacional de alimentos (mais especificamente Folhas de balanço publicadas pela FAO), os quais demonstraram aumento da homogeneidade do sistema alimentar global.

Por fim, destaca-se que esta tese apresenta um conjunto de evidências inéditas que reforçam as recomendações do Guia Alimentar para a População Brasileira e o debate sobre a necessidade de uma transição urgente do sistema alimentar global e dos padrões alimentares atuais, de forma a promover a produção e o consumo de uma variedade de alimentos *in natura* e minimamente processados de origem vegetal com drástica redução no consumo de alimentos ultraprocessados e consumo limitado de produtos de origem animal (principalmente por estratos populacionais que excedem as recomendações atuais de consumo). Tal transição é essencial para a conservação e restauração da agrobiodiversidade e consequente promoção de dietas e sistemas alimentares mais saudáveis e sustentáveis.

8. ANEXOS

I. PARECER DO COMITÊ DE ÉTICA EM PESQUISA

USP - FACULDADE DE SAÚDE PÚBLICA DA UNIVERSIDADE DE SÃO PAULO - FSP/USP

Plataforma Brasil

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Qualidade nutricional e impacto da dieta brasileira sobre a biodiversidade: desafios e soluções

Pesquisador: FERNANDA HELENA MARROCOS LEITE VILLAMARIN

Área Temática:

Versão: 1

CAAE: 26650219.3.0000.5421

Instituição Proponente: Faculdade de Saúde Pública USP/SP

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 3.789.508

Apresentação do Projeto:

Evidências demonstram que dietas monótonas e de baixa qualidade nutricional são responsáveis, mundialmente, por um maior número de mortes quando comparadas a outros fatores de risco relacionados à carga global de doenças. Além disso, a Sindemia Global –caracterizada pela ocorrência simultânea da desnutrição, obesidade e mudanças climáticas – está impedindo que os países promovam a melhoria das dietas e das condições nutricionais das populações. O principal objetivo deste projeto é avaliar o consumo alimentar da população brasileira, considerando, simultaneamente, sua qualidade nutricional e seu impacto sobre a biodiversidade; bem como identificar formas factíveis de otimizá-la em relação a essas duas dimensões. A análise do consumo alimentar será realizada por meio dos dados da Pesquisa de Orçamentos Familiares (POF) nos períodos de 2008/2009 e 2017/2018. Todos os alimentos e bebidas consumidos serão classificados de acordo com a classificação NOVA. Os métodos "riqueza de espécies" (Species Richness) e "Índice de Diversidade de Simpson" (Simpson's index of diversity) serão utilizados para
investigar a diversidade de espécies selvagens e domesticadas presente na dieta brasileira. A qualidade nutricional do consumo alimentar será investigada por meio do consumo de nutrientes e constituintes da dieta relacionados ao risco de obesidade e DCNTs, além de outros nutrientes consumidos de forma inadequada pela população. Serão investigados diferentes cenários de consumo alimentar com relação ao seu grau de
processamento e diversidade de espécies de origem vegetal. Por fim, indicadores ambientais serão

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utilizados, com o intuito de investigar o impacto de diferentes níveis de diversidade de espécies consumidas sobre a biodiversidade dos sistemas alimentares no contexto brasileiro.

Objetivo da Pesquisa:

Objetivo Primário:

O principal objetivo deste estudo é avaliar o consumo alimentar da população brasileira, considerando, simultaneamente, sua qualidade nutricional (com foco na diversidade da dieta) e seu impacto sobre a biodiversidade dos sistemas alimentares, bem como identificar formas factíveis de otimizá-la em relação a essas duas dimensões.

Objetivos Secundários:

• Analisar a diversidade de espécies selvagens e domesticadas que compõem diferentes padrões alimentares no Brasil no período de 2008/9, levando em conta as macrorregiões e estratos de renda da população;

• Investigar a evolução do consumo de alimentos ultraprocessados e seu impacto sobre a diversidade alimentar e, consequentemente, sobre a qualidade nutricional da dieta brasileira entre 2008/9 e 2017/18;

• Projetar a evolução da dieta brasileira (quanto à diversidade de espécies e qualidade nutricional), e o seu impacto sobre a biodiversidade para o próximo decênio, segundo diferentes cenários;

• Discutir possíveis soluções sobre as mudanças factíveis na dieta brasileira que simultaneamente melhorem sua qualidade nutricional e reduzam o seu impacto sobre a biodiversidade dos sistemas alimentares.

Avaliação dos Riscos e Benefícios:

Riscos:

O presente projeto pode ser considerado de baixíssimo risco em relação à pessoas quando consideramos que depende de uso de dados secundários de publicação do Instituto Brasileiro de Geografia e Estatística, sendo que as amostras populacionais não têm seus participantes identificados, mantendo-se o sigilo.

Benefícios:

O presente estudo tem o potencial de contribuir para as discussões internacionais sobre os impactos do consumo de alimentos ultraprocessados, de carnes em geral e de diferentes espécies sobre a biodiversidade, bem como para os debates relacionados aos desafios impostos pela Sindemia Global e sua inércia política - que vem impedindo os países de realizarem avanços com relação à má nutrição e aos riscos de saúde e ambientais associados a dietas não saudáveis. Os

achados dessa pesquisa podem, ainda, colaborar com grupos de pesquisa das áreas de Agricultura e Meio Ambiente – com o intuito de estabelecer metas e recomendações factíveis na dieta brasileira que simultaneamente melhorem sua qualidade nutricional e reduzam o seu impacto ambiental – além de enfatizar a importância de ações de melhorias dos sistemas alimentares por meio de objetivos políticos integrados entre as áreas da nutrição, saúde, economia e meio ambiente. Além disso, por meio da divulgação dos resultados desse estudo, pretende-se avaliar as melhores opções dentro dos padrões dietéticos já praticados no Brasil para moderar o consumo de alimentos que apresentam maiores impactos sobre a saúde humana e ecológica, principalmente quanto à biodiversidade brasileira – imprescindível para a
garantia da segurança alimentar e nutricional e à garantia do direito humano à alimentação saudável e adequada.Por fim, acredita-se que o presente estudo será capaz de aprofundar e reforçar as recomendações alimentares já presentes no Guia Brasileiro que visam a reduzir, de forma simultânea, os impactos do consumo alimentar atual na saúde, nutrição e meio ambiente; bem como promover sistemas alimentares mais saudáveis,
sustentáveis e justos.

Comentários e Considerações sobre a Pesquisa:
Pesquisa relevante e inovadora.

Considerações sobre os Termos de apresentação obrigatória:
Folha de rosto preenchida adequadamente. Não é apresentado TCLE porque a pesquisa trabalhará com dados de bancos públicos.

Recomendações:
Pela aprovação do projeto.

Conclusões ou Pendências e Lista de Inadequações:
Sem óbices éticos.

Considerações Finais a critério do CEP:

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1454151.pdf	03/12/2019 14:46:13		Aceito

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Folha de Rosto	PlataformaBrasilFernandaVillamarin.pdf	23/10/2019 12:49:42	FERNANDA HELENA MARROCOS LEITE	Aceito
Projeto Detalhado / Brochura Investigador	Projetodepesquisa.docx	23/10/2019 12:48:27	FERNANDA HELENA MARROCOS LEITE	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

SAO PAULO, 23 de Dezembro de 2019

Assinado por:
José Leopoldo Ferreira Antunes
(Coordenador(a))

Endereço: Av. Doutor Arnaldo, 715
Bairro: Cerqueira Cesar **CEP:** 01.246-904
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II. COMPROVANTE DE ACEITE E SUBMISSÃO DE ARTIGOS

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1 message

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02-Feb-2022
bmjgh-2021-008269.R1 - Ultra-processed foods should be central to global food systems dialogue and action on biodiversity

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Kind regards,

Dr. Seye Abimbola
Editor in Chief, BMJ Global Health

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BMJ Global Health - Manuscript ID bmjgh-2023-014322

BMJ Global Health <onbehalfof@manuscriptcentral.com> 23 October 2023 at 14:33
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23-Oct-2023

Dear Ms. Leite:

Your manuscript entitled "Methodology for determining the agrobiodiversity that underlies human diets: an application using Brazilian food purchase data" has been successfully submitted online and is presently being given full consideration for publication in BMJ Global Health.

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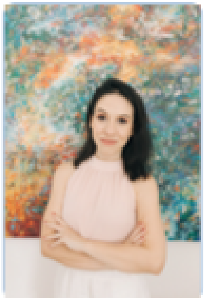
III. CURRÍCULO LATTES



Fernanda Helena Marrocos Leite Villamarin

Endereço para acessar este CV: http://lattes.cnpq.br/0213319172028616
ID Lattes: **0213319172028616**
Última atualização do currículo em 23/10/2023

Possui graduação em Nutrição (2009) e mestrado em Ciências da Saúde (2012) pela Universidade Federal de São Paulo (UNIFESP), e é doutoranda do Programa de Saúde Global e Sustentabilidade da Faculdade de Saúde Pública da Universidade de São Paulo (USP). Atuou como pesquisadora em políticas alimentares no Painel Global sobre Agricultura e Sistemas Alimentares para Nutrição (Global Panel on Agriculture and Food Systems for Nutrition), sediado no Centro de Desenvolvimento Internacional de Londres (London International Development Centre) da London School of Hygiene and Tropical Medicine, Londres, Reino Unido (2015-2018). Atuou no desenvolvimento de ações de assessoria aos municípios dos estados de São Paulo e Rio de Janeiro com enfoque na melhoria da execução e do monitoramento do Programa Nacional de Alimentação Escolar (PNAE). Desenvolveu, ainda, atividades de formação dos profissionais envolvidos nesta área pelo Centro Colaborador de Alimentação e Nutrição Escolar (CECANE) da Universidade Federal de São Paulo, junto ao Fundo Nacional de Desenvolvimento da Educação - FNDE (2012-2014). Atualmente, desenvolve trabalhos de consultoria nas áreas de segurança alimentar e nutricional e sistemas alimentares saudáveis e sustentáveis. **(Texto informado pelo autor)**

Identificação

Nome	Fernanda Helena Marrocos Leite Villamarin
Nome em citações bibliográficas	LEITE, F. H. M.;Leite, Fernanda Helena Marrocos;LEITE, FERNANDA H.M.;MARROCOS LEITE, FERNANDA HELENA;LEITE, FERNANDA HELENA M.;M. LEITE, FERNANDA H
Lattes iD	http://lattes.cnpq.br/0213319172028616

Endereço

Formação acadêmica/titulação

2019	Doutorado em andamento em Saúde Global e Sustentabilidade. Universidade de São Paulo, USP, Brasil. Título: Qualidade nutricional e impacto da dieta brasileira sobre a biodiversidade: desafios e soluções Orientador: Prof Dr Carlos Augusto Monteiro.
2010 - 2012	Mestrado em Programa Interdisciplinar em Ciências da Saúde. Universidade Federal de São Paulo, Baixada Santista, UNIFESP, Brasil. Título: Efeitos do ambiente nutricional no consumo de alimentos processados por crianças menores de dez anos no município de Santos, Ano de Obtenção: 2012. Orientador: Paula Andrea Martins. Bolsista do(a): Fundação de Amparo à Pesquisa do Estado de São Paulo, FAPESP, Brasil. Palavras-chave: Ambiente Nutricional; Consumo alimentar; alimentos processados; Crianças. Grande área: Ciências da Saúde Grande Área: Ciências da Saúde / Área: Nutrição / Subárea: Epidemiologia Nutricional.
2006 - 2009	Graduação em Nutrição. Universidade Federal de São Paulo, Baixada Santista, UNIFESP, Brasil. Título: Acesso a alimentos processados no perímetro de escolas públicas no município de Santos. Orientador: Paula Andrea Martina. Bolsista do(a): Fundação de Amparo à Pesquisa do Estado de São Paulo, FAPESP, Brasil.

Carlos Augusto Monteiro

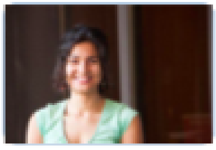
Bolsista de Produtividade em Pesquisa do CNPq - Nível 1A

Endereço para acessar este CV: http://lattes.cnpq.br/9217754427341680
ID Lattes: **9217754427341680**
Última atualização do currículo em 30/08/2023

A formação acadêmica do Professor Monteiro inclui graduação em Medicina, Residência e Mestrado em Medicina Preventiva, Doutorado em Saúde Pública, todos cursados na USP, e pós-doutorado no Instituto de Nutrição Humana da Columbia University. Sua carreira de pesquisador e orientador (já formou dezenas de mestres e doutores) foi feita no Departamento de Nutrição da Faculdade de Saúde Pública da USP, onde é Professor Titular desde 1989. Entre 1990 e 1992, trabalhou na Unidade de Nutrição da OMS em Genebra e foi professor visitante das universidades de Bonn e Genebra. É coordenador científico do Núcleo de Pesquisas Epidemiológicas em Nutrição e Saúde da USP (NUPENS/USP) desde 1992. De dezenas de projetos de pesquisa realizados na área da Nutrição em Saúde Pública, resultaram vários livros e mais de 250 publicações indexadas na Web of Sciences com mais de 20 mil citações (índice H: 70). É bolsista de produtividade científica do CNPq desde 1981 e pesquisador nível IA desde 1989. São destaques de sua produção científica voltada para o Brasil artigos sobre inquéritos populacionais em saúde e nutrição infantil realizados em São Paulo nas décadas de 70, 80 e 90, cujos resultados foram essenciais para redefinir o enfoque e o conteúdo dos programas nutricionais nas unidades básicas de saúde de São Paulo e, posteriormente, de todo o país; projeto temático FAPESP de resgate e interpretação das tendências temporais das condições de saúde e nutrição da população brasileira na segunda metade do século XX, do qual resultou livro ganhador do prêmio Jabuti de melhor livro do ano na categoria Ciências Naturais e Medicina; análises das Pesquisas de Orçamentos Familiares do IBGE, que trouxeram nova e crítica visão para o problema da segurança alimentar no país; desenvolvimento e validação de um sistema nacional de monitoramento de fatores de risco para doenças crônicas baseado em entrevistas telefônicas, ganhador do Prêmio de Incentivo em Ciência e Tecnologia para o SUS de 2005 e inspirador do sistema VIGITEL implantado desde 2006 pelo Ministério da Saúde nas 26 capitais de estados brasileiros e Distrito Federal; estudos que documentaram o declínio excepcional da desnutrição infantil no Brasil entre 1996 e 2007 e quantificaram o papel da redução da pobreza e da extensão de cobertura de serviços públicos essenciais naquele declínio; e estudos sobre padrões de alimentação e saúde no Brasil, que orientaram a elaboração do Guia Alimentar para a População Brasileira 2014. Como parte de sua produção científica de impacto internacional, destacam-se estudos sobre determinantes da tendência secular do aleitamento materno e da mortalidade infantil em países em desenvolvimento; criação de novos indicadores para a avaliação antropométrica do estado nutricional de populações; estudos sobre o fenômeno da transição alimentar e nutricional nos países em desenvolvimento, desenvolvimento do sistema NOVA de classificação de alimentos, que se tornou referência mundial para a análise do efeito do processamento de alimentos na qualidade da dieta e na saúde humana e dezenas de estudos populacionais que demonstraram a associação entre o consumo de alimentos ultraprocessados e doenças crônicas não transmissíveis. Desde 2020 coordena o estudo de coorte NutriNet Brasil, que acompanha a alimentação e a saúde de mais de 100 mil brasileiros. É Editor Científico da Revista de Saúde Pública e, desde 2010, integra, o comitê Nutrition Guidance Expert Advisory Group da OMS. Em 2010, foi o terceiro brasileiro a ganhar o prêmio Abraham Horwitz de Liderança Científica em Saúde nas Américas outorgado pela OPAS todos os anos ao pesquisador latinoamericano que mais se destacou no campo. É membro da Academia Brasileira de Ciências desde 2007. Em 2018, 2019, 2020, 2021 e 2022, foi relacionado pela Web of Sciences/Clarivate?s Analytics entre os 1% dos cientistas da grande área das Ciências Sociais cujos artigos científicos alcançaram maior repercussão na literatura científica. **(Texto informado pelo autor)**

Identificação

Nome	Carlos Augusto Monteiro
Nome em citações bibliográficas	Monteiro CA ou Monteiro C;Monteiro, Carlos Augusto;Monteiro, Carlos A;Monteiro, Carlos;Monteiro, Carlos A.; MONTEIRO, C. A.;MONTEIRO, C.;Monteiro, C;MONTEIRO,



Neha Khandpur

Endereço para acessar este CV: http://lattes.cnpq.br/9849350846897048
ID Lattes: **9849350846897048**
Última atualização do currículo em 01/09/2023

Meus interesses de pesquisa concentram-se amplamente na influência que políticas e fatores ambientais exercem sobre as escolhas alimentares e os comportamentos do estilo de vida, e como eles podem ser aproveitados para criar ambientes de nutrição mais saudáveis e prevenir a obesidade e as doenças crônicas. Na minha pesquisa atual, eu uso métodos qualitativos e experimentais para estimar a influência que as políticas alimentares, como os rótulos nutricionais, têm na compreensão do consumidor e na seleção de alimentos. Eu uso métodos epidemiológicos para estudar associações entre o consumo de alimentos, particularmente de alimentos ultraprocessados, e o risco de doenças crônicas em pesquisas nacionalmente representativas na Colômbia e em coortes de adultos e crianças nos EUA, no Reino Unido e na Índia. **(Texto informado pelo autor)**

Identificação

Nome	Neha Khandpur
Nome em citações bibliográficas	KHANDPUR, N.;KHANDPUR, NEHA;KHANDPUR, N
Lattes iD	http://lattes.cnpq.br/9849350846897048
Orcid iD	? https://orcid.org/0000-0002-4766-8361

Endereço

Endereço Profissional	Universidade de São Paulo, Faculdade de Saúde Pública. Avenida Doutor Arnaldo - de 601/602 ao fim Sumaré 01255000 - São Paulo, SP - Brasil Telefone: (55) 1197087868

Formação acadêmica/titulação

2011 - 2016	Doutorado em Public Health Nutrition. Harvard T.H. Chan School of Public Health, HSPH, Estados Unidos. Título: Creating healthy nutrition environments, Ano de obtenção: 2016. Orientador: Walter Willett. Coorientador: Kirsten Davison. Bolsista do(a): Harvard University, HU, Estados Unidos. Palavras-chave: Home nutrition environments; Consumer nutrition environments; Feeding practises; Nutrition labels; Obesity epidemiology.
2005 - 2006	Mestrado em Physical Activity, Nutrition and Public Health. University of Bristol, BRISTOL, Inglaterra. Título: A systematic review of observational studies evaluating the effects of physical activity on the risk of ovarian cancer, Ano de Obtenção: 2006. Orientador: Kenneth Fox. Palavras-chave: Physical activity; Systematic review; Cancer prevention.
2003 - 2004	Graduação em Sports Science and Nutrition. SNDT Women's University, SNDT, Índia. Título: Utilization of protein supplements by the human body.
2000 - 2003	Graduação em Chemistry, Zoology, Nutrition and Dietetics. Bangalore University, BU, Índia. Título: Prevalence of obesity and food consumption patterns of obese children between the ages of 5 and 14 years.

Pós-doutorado

2016	Pós-Doutorado. Universidade de São Paulo, USP, Brasil. Bolsista do(a): Fundação de Amparo à Pesquisa do Estado de São Paulo, FAPESP, Brasil. Grande área: Ciências da Saúde Grande Área: Ciências da Saúde / Área: Saúde Coletiva / Subárea: Saúde Pública. Grande Área: Ciências da Saúde / Área: Saúde Coletiva / Subárea: Epidemiologia.