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2. Publications and Scientific Contributions

Paper I

Maya, C., Sterling, K., Rukov, J. L., & Roos, N. (2023). Perception of edible insects and insect-based foods among children in Denmark: educational and tasting interventions in online and in-person classrooms. *Journal of Insects as Food and Feed*, 9(8), 989-1001.

Paper II

Maya, C., Cunha, L. M., de Almeida Costa, A. I., Veldkamp, T., & Roos, N. (2022). Introducing insect- or plant-based dinner meals to families in Denmark: study protocol for a randomized intervention trial. *Trials*, 23(1), 1-9.

Paper III

Maya, C., Wilderspin, D.E., Costa, A.I.A., Cunha, L.M., & Roos, N. Introducing insect- or plant-based dinner meals slightly reduced meat consumption in Danish families: results of a randomized intervention study. *Manuscript in progress*.

Other publications

The following paper was not included in the thesis:

Van Huis, A., Rumpold, B., Maya, C., & Roos, N. (2021). Nutritional qualities and enhancement of edible insects. *Annual review of nutrition*, 41, 551-576.

4. Summary in English

Background: Addressing the environmental impact necessitates a dietary shift towards more sustainable daily food choices, specifically reducing meat intake. Edible insects are a compelling alternative, providing a protein-rich source that holds potential to replace conventional meats. The shift involves more than just matching nutritional content. Meat consumption is deeply rooted in cultural norms, traditions, and individual identities, leading to resistance against its reduction or substitution. Challenges arise from psychosocial barriers, including meat attachment, disgust, and neophobia. Despite insects offering resource efficiency and nutrition – which varies with species, life stages, and rearing conditions – their integration into Western diets remains tentative. To harness the environmental and nutritional advantages of edible insects, their integration into regular meals is imperative, transcending their current status as occasional novelties. This requires strategies like targeting family meals and younger audiences. A nuanced approach, considering cultural and psychological factors, is vital to gauge the actual substitutive potential of insect-based foods, ensuring they meet and align with consumer expectations.

Objectives: The main objective of this thesis is to assess the potential of edible insects as meat replacements in the daily Danish diet. The first specific objective was to investigate the effects of exposing school children to educational and tasting interventions on the perception of edible insects and insect-based foods using online and in-person classrooms. The second specific objective was to investigate the impact of exposing families to insect-based or plant-based dinner menus on dietary pattern, meat intake, and protein intake over a six-week intervention period.

Methods: **Paper I** consisted of two sub-studies. The online classroom used a simple intervention design where the perception of two insect-based were measured after exposure to the information session and tasting among 220 schoolchildren aged 12-15 years. Online sessions (OS) 1 and 2 were conducted with cricket-based flatbread. OS3 incorporated a cooking and tasting session of a dhal-style dish using a cricket spice mix. The in-person classroom intervention (IPI) was a single-arm pre-post study design composed of a lesson, food tasting, and a question-and-answer session with designated questionnaires to 65 eighth grade children. The tasting offered buffaloworm falafel. **Paper II** describes the protocol of the main dietary intervention. **Paper III** was a two-arm randomized equivalence intervention trial. The participants consisted of families: one adult and one 8–10 year-old child. The families were provided products incorporating either

insect-based or plant-based protein suited to replace meat in 3 weekly dinner meals for 6 weeks. The six insect-based products in the experimental menu were developed by SUSINCHAIN project partners. The plant-based menu featured market-available products that closely matched the insect-based items in presentation and nutritional composition. The portions were estimated to replace, on average, 20% of the weekly meat protein intake for one adult and one child. Participants filled out questionnaires on food neophobia, disgust, disgust towards insects, exposure to edible insects, meat attachment (adults only), and food acceptability and feedback. Dietary assessments were conducted using 4-day dietary registrations at baseline and endline, as well as daily food records.

Results: In **Paper I**, of the 220 responses from OS1-3, 96% of children completed the OS1 questionnaire, 76% completed OS2, and 45% completed OS3. From the in-person interventions, 65 responses were collected. Notably, as tasks increased in the online sessions, the response rate fell. After the in-person classroom session, children saw positive correlations between the societal need for sustainable foods and their own willingness to eat insects. The post-intervention data suggested that both the educational lesson and tasting sessions effectively conveyed the option of edible insects as a sustainable protein source. The insect-based products we presented received largely positive reviews. In **Paper III**, 80 families (80 adults and 80 children) enrolled, of which 65 completed the intervention. Although the intervention aimed for a 20% meat replacement, the results were modest. Neither the adults nor the children achieved the 20% target replacement. Adults in the insect-based menu reduced meat consumption by an average of 5.5%, while children achieved a 2.3% reduction. Conversely, the plant-based menu reduced meat consumption by an average of 9.0% for adults and 4.3% for children. Meat attachment was the only psychosocial factor that had a statistically significant impact on daily meat protein intake. While the frequency of meat meals decreased, portion sizes did not change. Notably, participants following the insect-based menu exhibited a higher dropout rate.

Discussion and Conclusion: The effectiveness of classroom interventions in promoting edible insects was evidenced by post-intervention data. This data demonstrated increased positive correlations between recognizing the importance of sustainable foods and a willingness to eat insects. Children possess prior knowledge of sustainability issues, but this does not necessarily translate to viewing insects as a sustainable choice, especially with the interference from food neophobia and disgust. Educational interventions can aid in bridging this disconnect and positive influence acceptability towards edible insects and lessen feelings of disgust toward insect consumption.

Incorporating edible insects into a regular dinner meals pose more challenges than occasional consumption. In the dietary intervention, a slight reduction in meat consumption among participants indicated the potential for insect-based diets to be introduced into the daily diet, but also emphasized that obstacles that still exist. Improving the sensory characteristics of alternative proteins could increase their acceptance across age groups. Introducing insect-based proteins in two dinner meals per week can be a starting point to decrease meat protein intake. Setting a 20% weekly meat replacement target with insect protein posed an ambitious challenge for food innovators. Meat replacement targets can be modified to better fit future interventions.

Psychosocial factors, notably meat attachment, play a pivotal role in the acceptance of edible insects. Children's dietary patterns during the intervention paralleled those of adults, suggesting a shared adaptability. However, further research is needed since children are exposed to different environments, such as schools, and tend to become less reliant on their parent's food choices. As familiarity with edible insects grows, along with increasing knowledge of sustainability and improvements in meat substitutes, research methodologies should be adapted accordingly.

The successful integration of edible insects into Western diets depends on multiple factors: product presentation, taste, and previous consumer experiences. Using familiar dishes that incorporate insects can capture children's interest, aligning with the preference for 'invisible' insect ingredients. Factors such as taste, texture, and familiarity dictate the reception of insect-based and other alternative proteins. Emphasizing the benefits and refining sensory characteristics can help in the mainstream acceptance of edible insects.

The pathway to sustainable diet shifts depends on both refining insect-based food quality and understanding consumer behavior. Achieving this shift requires a multifaceted approach considering the existing dietary habits of adults and children, psychosocial barriers, particularly meat attachment, and the reception to novel and nutritious protein sources.

5. Dansk Resume

Baggrund: For at adressere miljøpåvirkningen kræves der en ændring i kosten mod mere bæredygtige daglige madvalg, specifikt en reduktion af kødindtag. Spiselige insekter, en god kilde til protein, er et overbevisende alternativ, der har potentialet til at erstatte konventionelle kødtyper. Kostændringen involverer dog mere end bare at matche det ernæringsmæssige indhold. Kødfordbrug er dybt forankret i kulturelle normer, traditioner og individuelle identiteter, hvilket fører til modstand mod dets reduktion eller erstatning. Udfordringerne kommer fra psykosociale barrierer, herunder tilknytning til kød, væmmelse og neofobi. På trods af at insekter tilbyder god ernæring og en effektiv brug af ressourcer – hvilket varierer alt efter arter, livsfasen og opdrætsforhold – er deres integration i vestlige kostvaner stadig langsom. For at udnytte de miljømæssige og ernæringsmæssige fordele ved spiselige insekter, er det afgørende, at de integreres i regelmæssige måltider, og ikke blot optræder som et lejlighedsvist nyt element. Dette kræver strategier såsom at målrette familiemåltiderne og det yngre publikum. En nuanceret tilgang, der tager hensyn til kulturelle og psykologiske faktorer, er afgørende for at vurdere det faktiske erstatningspotentiale af insektbaserede fødevarer, og sikre at de opfylder og stemmer overens med forbrugerforventninger.

Formål: Hovedformålet med denne afhandling er at vurdere potentialet for spiselige insekter som erstatning for kød i den daglige, danske kost. Det første specifikke mål var at undersøge effekten af at udsætte skolebørn for undervisnings- og smagsinterventioner på opfattelsen af spiselige insekter og insektbaserede fødevarer ved hjælp af online og fysiske klasseværelser. Det andet specifikke mål var at undersøge virkningen af at udsætte familier for insektbaserede eller plantebaserede middagsmenuer på kostmønster, kødindtag og proteinindtag over en seks ugers interventionsperiode.

Metoder: Artikel I bestod af to delstudier. Det online klasseværelse anvendte et simpelt interventionsdesign, hvor opfattelsen af to insektbaserede retter blev målt efter eksponering for informationssessionen og smagning blandt 220 skolebørn i alderen 12-15 år. Online sessioner (OS) 1 og 2 blev udført med fladbrød baseret på fårekylinger. OS3 indeholdt en madlavnings- og smagningssession af en dhal-lignende ret ved hjælp af en krydderiblanding baseret på fårekylinger. Den fysiske klasseværelsesintervention (IPI) var et enkelt-armet pre-post studiedesign bestående af en lektion, madsmagning og en spørgerunde med udpegede spørgeskemaer til 65 ottendeklasses elever. Smagningen bestod af falafler bestående af

bøffelorm. **Artikel II** beskriver protokollen for den vigtigste kostintervention. **Artikel III** var et to-armet, randomiseret ækvivalensinterventionsforsøg. Deltagerne bestod af familier: en voksen og et 8-10 år gammelt barn. Familierne fik udleveret produkter, der inkorporerede enten insektbaseret eller plantebaseret protein egnet til at erstatte kød i 3 ugentlige middagsmåltider i 6 uger. De seks insektbaserede produkter i den eksperimentelle menu blev udviklet af SUSINCHAIN projektpartnerne. Den plantebaserede menu indeholdt markedsførte produkter, der nøje matchede de insektbaserede varer i præsentation og ernæringsmæssig sammensætning. Portionerne blev estimeret til at erstatte i gennemsnit 20% af det ugentlige kødproteinindtag for hhv. en voksen og et barn. Deltagerne udfyldte spørgeskemaer om madneofobi, madvæmmelse, væmmelse overfor insekter, eksponering for spiselige insekter, kødtilknytning (kun voksne) og hvor acceptabel maden var, samt et feedback skema. Kostvurderinger blev foretaget ved hjælp af 4-dages kostregistreringer ved baseline og endline samt daglige fødevareregistreringer.

Resultater: I **Artikel I**, ud af de 220 svar fra OS1-3, gennemførte 96% af børnene OS1-spørgeskemaet, 76% gennemførte OS2, og 45% gennemførte OS3. Fra de fysiske interventioner blev 65 svar indsamlet. Det er værd at bemærke, at svarraten faldt, efterhånden som opgaverne blev flere i de online sessioner. Efter den fysiske klasseværelsessession så børnene positive korrelationer mellem samfundets behov for bæredygtige fødevarer og deres egen vilje til at spise insekter. Data efter interventionen antydede, at både den pædagogiske lektion og smagssessionerne effektivt formidlede muligheden for spiselige insekter som en bæredygtig proteinkilde. De insektbaserede produkter, vi præsenterede, modtog overvejende positive anmeldelser. I **Artikel III** tilmeldte 80 familier (80 voksne og 80 børn) sig, hvoraf 65 gennemførte interventionen. Selvom interventionen sigtede mod en 20% køderstatning, var resultaterne beskedne. Hverken de voksne eller børnene opnåede den 20% målrettede erstatning. Voksne der fulgte den insektbaserede menu reducerede kødforbruget med et gennemsnit på 5,5%, mens børn opnåede en reduktion på 2,3%. Omvendt reducerede den plantebaserede menu kødforbruget med et gennemsnit på 9,0% for voksne og 4,3% for børn. Kødtilknytning var den eneste psykosociale faktor, der havde en statistisk signifikant indvirkning på det daglige kødproteinindtag. Selvom frekvensen af kødmåltider faldt, ændredes portionernes størrelse sig ikke. Det er værd at bemærke, at deltagerne, der fulgte den insektbaserede menu, viste en højere frafaldsrate.

Diskussion og Konklusion: Effektiviteten af klasseværelsesinterventioner på at fremme spiselige insekter blev bevist ved data efter interventionen. Disse data viste en øget positiv korrelation mellem anerkendelse af betydningen af bæredygtige fødevarer og viljen til at spise

insekter. Børn besidder forhåndskendskab til bæredygtighedsproblemer, men dette oversættes ikke nødvendigvis til at se insekter som et bæredygtigt valg, især med forstyrrelse fra madneofobi og væmmelse. Uddannelsesinterventioner kan hjælpe med at bygge bro over denne diskrepans og positivt påvirke hvorvidt det ses som værende acceptabel at spise insekter, og at mindske følelser af væmmelse overfor at spise insekter.

At inkorporere spiselige insekter i regelmæssige middagsmåltider byder på flere udfordringer end ved lejlighedsvist brug. I kostinterventionen indikerede en let reduktion i kødforbruget blandt deltagerne potentialet for insektbaserede diæter at blive introduceret i den daglige kost, men understregede også de forhindringer, der stadig findes. Forbedring af alternative proteiners sensoriske karakteristika kan øge deres accept på tværs af aldersgrupper. Introduktion af insektbaserede proteiner i to middagsmåltider om ugen kan være et udgangspunkt for at nedsætte kødproteinindtaget. At sætte et 20% ugentligt køderstatningsmål med insektprotein udgjorde en ambitiøs udfordring for fødevarerinnovatører. Køderstatningsmål kan justeres for bedre at passe til fremtidige interventioner.

Psykologiske faktorer, især kødtilknytning, spiller en afgørende rolle for accept af spiselige insekter. Børns kostvaner under interventionen fulgte de voksnes, hvilket antyder en delt tilpasningsevne. Dog er yderligere forskning nødvendig, da børn udsættes for forskellige miljøer, såsom skoler, og har tendens til at blive mindre afhængige af deres forældres madvalg. Efterhånden som fortroligheden med spiselige insekter vokser, sammen med stigende viden om bæredygtighed og forbedringer i køderstatninger, bør forskningsmetodikker tilpasses derefter.

Den succesfulde integration af spiselige insekter i vestlige diæter afhænger af flere faktorer: produktpræsentation, smag og tidligere forbrugererfaringer. Brug af velkendte retter, der inkorporerer insekter, kan fange børns interesse, hvilket stemmer overens med præferencen for 'usynlige' insektingredienser. Faktorer som smag, tekstur og fortrolighed dikterer modtagelsen af insektbaserede og andre alternative proteiner. At fremhæve fordelene og finjustere sensoriske karakteristika kan hjælpe med bred accept af spiselige insekter.

Vejen til bæredygtige kostskift afhænger af både raffinering af insektbaseret fødevarer kvalitet og forståelse af forbrugeradfærd. At opnå denne ændring kræver en multifacetteret tilgang, der tager hensyn til eksisterende kostvaner hos voksne og børn, psykosociale barrierer, især kødtilknytning, og modtagelse af nye og næringsrige proteinkilder.

6. Introduction

The environmental impacts of animal-based proteins, particularly meat, stresses the need for a more sustainable food system ^[1,2]. Conventional livestock farming stands as a significant contributor to greenhouse gas emissions, resource depletion, and environmental pollution ^[3]. These concerns have prompted the search for more sustainable protein alternatives ^[4,5]. Edible insects are a viable option, offering high-quality protein that could potentially replace meat in our diets ^[6]. However, the shift from meat to alternative proteins isn't merely a question of nutritional equivalence. For many, meat consumption intertwines with cultural norms, traditions, and personal identities ^[7]. As such, there exists an inherent resistance to reducing meat consumption or adopting meat substitutes. Psychosocial barriers, such as a strong meat attachment and reluctance towards unfamiliar foods, challenge this transition ^[8,9]. These barriers, deeply anchored in cultural and psychological contexts, influence our dietary habits and dictate perceptions of new food sources ^[10].

Edible insects, in comparison to traditional animal-based proteins, typically offer greater resource efficiency while still being nutritious ^[11,12]. It's important to note, though, that the nutritional profile of these insects can differ based on species, developmental stages, and rearing methods ^[13]. Still, their potential for inclusion in the human diet remains promising. Despite the documentation of over 2,000 edible insect species worldwide ^[14], Western consumers remain hesitant. In order for edible insects to significantly address environmental concerns, they must transition from being novel adventurous snacks to staple dietary components ^[15]. A promising strategy involves introducing them in family dining settings and to younger demographics. Early exposure can foster knowledge on the importance of planetary health ^[16] and encourage broader acceptance of diverse food sources ^[17]. Schools, for instance, represent a practical channel for such initiatives. Previous studies have been conducted, but outcomes differ based on age, country, and the nature of the intervention, so more research is warranted ^[18-22].

However, as highlighted earlier, such shifts are not straightforward. Beyond presenting palatable products, introducing a novel food source requires a meticulous, phased approach. This involves evaluating the ideal substitutive potential of edible insect proteins, as actual consumption patterns may diverge from expectations. Thus, assessing how effectively edible insect protein can serve as a realistic meat substitute is crucial.

7. Objectives of the PhD thesis

The main objective of this thesis is to assess the potential of edible insects as meat replacements in the daily Danish diet.

The specific objectives were:

1. To investigate the effects of exposing school children to educational and tasting interventions on the perception of edible insects and insect-based foods using online and in-person classrooms (**Paper I**).
2. To investigate the impact of exposing families to insect-based or plant-based dinner menus on dietary pattern, meat intake, and protein intake over a six-week intervention period (**Papers II and III**).