

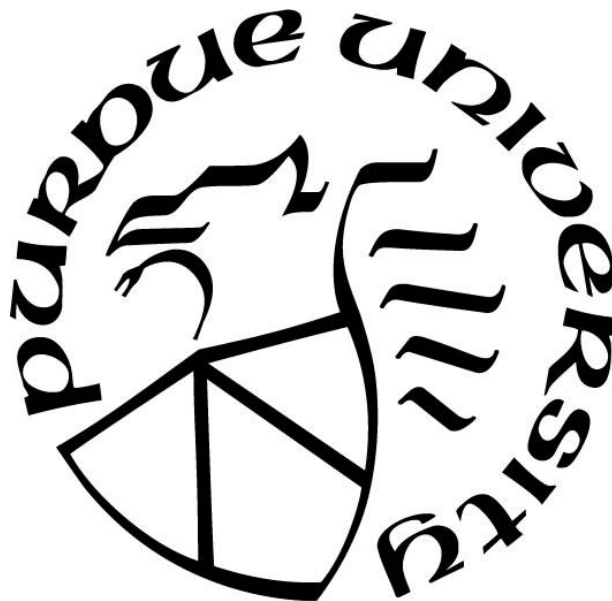
**POULTRY CONSUMPTION AND HUMAN HEALTH: HOW MUCH IS
REALLY KNOWN?
A SYSTEMATICALLY SEARCHED SCOPING REVIEW AND
RESEARCH PERSPECTIVE**

by
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A Thesis

*Submitted to the Faculty of Purdue University
In Partial Fulfillment of the Requirements for the degree of*

Master of Science



Department of Nutrition Science
West Lafayette, Indiana
May 2021

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*To Doris Clark, who taught me the importance of laughing unabashedly, loving whole-heartedly,
and always having a bright pink lipstick on hand.*

*To Bill Clark, who taught me how to play poker and to be a good sport when he did not let a
four-year-old win.*

*To Helen Sands, who taught me what patience and kindness mean, and that nothing can stand in
the way of a woman and her education.*

*To Bill Sands, who taught me people's picadilloes make them more endearing, and that true
solace can be found in books.*

ACKNOWLEDGMENTS

To my major professor, Dr. Wayne Campbell, for giving me so many opportunities to learn and grow over the last three years. Thank you for taking on and believing in a chemistry student with no background in nutrition.

To my committee members: Dr. Tzu-Wen Cross and Dr. David Waters, for your time and energy spent helping me. To the members of the Campbell lab group: Jan Green for providing candy, political updates, and needed advice. Yu Wang for patiently walking me through things, sometimes several times, and always smiling. Erica Hill for making life better both inside and outside of the lab. Cassi Uffelman for providing helpful insights and sweet, uplifting words. Gavin Connolly for his diligence, thoroughness, and Irish accent. Gretchen Weise, for always being empathetic and kind. Lauren O'Connor, for your love of science, patience, and willingness to help in all aspects. Robert Bergia and Josh Hudson, for keeping my ego in check and your mentorship. To my friend Lily Darbishire, thank you for all that you do each and every day, and for sharing your amazing family with me for the last three years.

To my parents, Bill and Kathy Clark, thank you for the frequent pep talks and demonstrating what a true passion for learning looks like. I would never have gotten this far without your encouragement, both intellectual and emotional. To William and Bailey, thank you for all the puppy pictures and love. To Patrick, for making me laugh when I am stressed and for always lifting me up. I appreciate each of you so much.

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ABSTRACT

The purpose of this scoping review was to systematically search and chronicle the available scientific literature pertinent to chicken/poultry intake and human health. The protocol was uploaded to Open Science Framework (<https://osf.io/2k7bj/>) and was conducted in accordance with recommended guidelines from PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) extension for scoping reviews (PRISMA-ScR). Articles and scientific literature of all types (observational, experimental, narrative/literature reviews, systematic reviews and meta-analyses) assessing chicken/poultry intake and human health were included. A total of 13,141 articles were identified and 540 met the inclusion criteria. Among these 540 articles, 212 articles focused on cancer morbidity and mortality; 22 on cancer risk factors; 41 on cardiovascular disease (CVD) morbidity and mortality; 52 on CVD risk factors; 32 on diabetes morbidity and mortality; 33 on diabetes risk factors; 42 articles on body weight and body composition, and 181 categorized as “Other”, which included nutrient status, psychological well-being/mental health, cognitive outcomes, microbiome outcomes, chronic kidney disease, non-alcoholic fatty liver disease, skin disorders, and fertility, among others. Among the included articles, 373 were observational, 77 were reviews and meta-analyses and 70 were experimental.

This scoping review systematically identifies scientific literature pertinent to poultry intake and all facets of human health. It provides the types of article designs that exist for each designated health outcome, as well as the years in which research was published by health outcome. This review highlights areas where poultry research is apparently lacking. The influences of processed poultry in human health outcomes should be assessed, and cooking methods of poultry should be reported in both RCTs and OBS articles to understand the role of poultry more completely in human health outcomes. This review also provides suggestions for potential RCTs that would help to elucidate the effects of consuming fresh versus processed poultry products on cardiometabolic and cancer risk factor outcomes. Additionally, this review gave guidance on where systematic reviews assessing poultry intake and the following health outcomes are warranted: body mass index/overweight/obesity, CVD morbidity and mortality, and T2DM risk factors and morbidity.

CHAPTER 1: INTRODUCTION

The Dietary Guidelines for Americans, 2020-2025 (DGA) defines poultry as all forms of chicken, turkey, duck, geese, guineas, and game birds (e.g., quail and pheasant).¹ Chicken provides 13.9% of animal protein consumed in the U.S. and 7.2% of total protein intake, while turkey, duck and other poultry provides 0.2% of animal protein, and 0.1% of total protein². By far, chicken meat is the most consumed meat in the U.S. per capita. The amounts of chicken and total poultry consumed have steadily increased, more than tripling since 1960 to the most recent reports in 2020².

The U.S. public generally considers poultry meat as a healthy food, as poultry provides high-quality protein and other nutrients and is often lower in fat than meat products from other animal sources. Additionally, poultry meat is generally affordable and easily accessible, leading to high rates of consumption globally. The DGA recommends consuming protein foods, including poultry, as a core element of a healthy dietary pattern. The DGA specify that poultry is a nutrient-dense food when prepared with little added sugar, saturated fat, or sodium. The DGA also specify that most poultry intake should be fresh, frozen or canned, and should be lean cuts of poultry, like chicken breast or ground turkey. Processed poultry intake, like cold cuts and sausages, should be kept to a minimum¹.

The forms of poultry consumed by Americans, however, are not necessarily in line with the guidance provided by the DGA. According to NHANES data from 2007-2010, whole pieces of chicken were the number one source of total protein intake, with no specification of cooking method¹. Cold cuts and cured meats, including poultry, accounted for 3.6% of an adult's total protein intake, making processed meats the number two source of total protein¹. NHANES data from 2015-2016 further underscores the difference between the DGA poultry recommendations and the actual intake of American adults. 19.2% of total poultry, and 22.3% of chicken consumed in the U.S. was purchased from a fast-food restaurant³.

Rigorous scientific assessments to bolster the claim that poultry is “healthy” are not abundant. Although primary research articles have included assessments of how poultry consumption influences various facets of health, a systematic search of the literature designed to chronicle the body of knowledge to date is lacking. Due to the discrepancy between the DGA recommendations and actual poultry intake, chronicling the types of poultry (both processing and

cooking methods) assessed in the literature is of great interest. A scoping review compiling articles regarding the relationship between and effects of consuming various poultry products on human health outcomes is warranted.

The purpose of this scoping review was to chronicle literature regarding poultry intake and human health outcomes, to uncover areas of poultry research that are lacking, and to provide a research perspective on the current state of poultry research. The review encompassed articles assessing the intake of poultry of all types. The population of interest was humans of all ages, races, geographical locations, and disease status. The health outcomes of interest included chronic diseases (i.e., obesity, cardiovascular disease (CVD), type 2 diabetes mellitus (T2DM), and cancer), and all other facets of human health. Articles and scientific literature of all types (observational, experimental, narrative/literature reviews, systematic reviews, and meta-analyses) were included. This review did not present the study results, nor did it assess the quality of included literature.

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CHAPTER 2. LITERATURE REVIEW

This thesis consists of a scoping review amassing articles regarding the relationship between and effects of consuming poultry products on human health outcomes. A scoping review was chosen to answer the research questions of “what scientific literature currently exists that is pertinent to poultry intake and human health?” and “what are the current knowledge gaps and how could these be addressed?” The following literature review elucidates the methodology of scoping reviews and provides a rationale for choosing a scoping review for this topic.

What is a scoping review?

A scoping review serves to synthesize the literature on a specific topic. From Arksey and O'Malley, the authors of the first methodological framework for conducting a scoping study: “scoping studies aim to map rapidly the key concepts underpinning a research area and the main sources and types of evidence available, and can be undertaken as standalone projects in their own right, especially where an area is complex or has not been reviewed comprehensively before”.¹ A more recent definition from Daudt et al. provides more guidance: “scoping studies aim to map the literature on a particular topic or research area and provide an opportunity to identify key concepts, gaps in the research; and types and sources of evidence to inform practice, policymaking, and research”.² Of note, there are inconsistencies in methodology across this relatively new synthesis process. Tricco et al. provided a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Extension for Scoping Reviews Checklist (PRISMA-ScR) to improve methodological and reporting quality by providing key items to report for scoping reviews in 2018.³

Systematic review or scoping review?

Scoping reviews are useful tools when the research question is broad. Scoping reviews can be used to chronicle and report on the types of articles or studies that exist for a broader research question, and to report pertinent information about the types of literature identified. Scoping reviews are also useful to highlight gaps in the knowledge and can be used to guide future research directions. Systematic reviews are geared toward assessing a more specific

research question and delineating the findings of relevant studies. Scoping reviews can be used as a tool to guide more specific research questions for a future systematic review.

What are other types of reviews?

Narrative Review: Narrative reviews are qualitative in design, and do not utilize a systematic search process to identify included articles. Due to the lack of a systematic search, a narrative review can contain some element of selection bias, as the included articles are entirely dependent upon the authors' discretion.⁴

Mapping Review: Mapping reviews are like scoping reviews, applying a systematic search to investigate the state of knowledge and identify knowledge gaps. Mapping reviews utilize visual representations of results, where scoping reviews may not³.

Systematic Review: Systematic reviews utilize a systematic search of literature and a priori data extraction process to identify and synthesize all relevant articles or studies to answer a specific research question.

Meta-Analysis: Meta-analyses use statistics to synthesize data from multiple studies, providing an overall quantitative estimate (risk ratio, hazard ratio, etc). Meta-analyses can be conducted within a systematic review or can be used to pool data from select studies that were not identified via a systematic search.

Umbrella Review: An umbrella review is a systematically searched synthesis of existing systematic reviews on a specific topic.

Why a scoping review?

A scoping review was chosen as the research questions are extremely broad. The authors were interested in identifying and chronicling the available evidence, and not to report on the results of studies identified as relevant. Thus, a scoping review was the appropriate type of review to answer the research questions, as well as to provide guidance for potential future systematic reviews.

What is the methodology of a scoping review?

The PRISMA-ScR checklist³ contains twenty essential and two optional reporting requirements. These include identifying the report as a scoping review in the title of the manuscript and providing an abstract. Authors should give a rationale for conducting a scoping review and explicitly delineating the objectives of the review. An *a priori* protocol should be provided. The inclusion and exclusion criteria should be presented, and a rationale should be provided. The full systematic search should be reported, including any filters used and dates searches were conducted. Two researchers should independently complete selection of sources and data charting, with results crosschecked for accuracy. Authors should provide information on how results were synthesized. The results of the study selection process should be presented in a flow diagram. The characteristics and results of each source should be presented and synthesized to relate to the original research question and objectives. The discussion should include a summary of the evidence, the potential limitations of the scoping review, and a conclusion that summarizes the results as they relate to the research question and provide guidance for next research steps. Funding should also be reported. The two optional items are critical appraisals of sources of evidence themselves, as well as the sources of evidence found within these sources.

What databases were selected for this scoping review?

This scoping review searched four databases for potentially relevant articles: PubMed, CINAHL, Cochrane Library, and Scopus. PubMed was searched because it is one the premier biomedical databases. CINAHL is a strong allied health database that is often included in searches to supplement PubMed as it indexes some additional resources than what may be found using solely PubMed. Cochrane Library not only produces their own systematic reviews, but they also aggregate data from PubMed and Embase. Purdue University does not have access to Embase, thus including Cochrane allowed the researchers access to journal articles indexed in Embase. Scopus was included because it has a broader scientific database that indexes more resources than the other databases. This database required a stricter search strategy due to the size of their indexing library, necessitating a refinement of the search to focus on medical literature.

To note, there is overlap across these resources. The goal of a scoping review is to discover all the evidence that meets our inclusion criteria, necessitating the use of several databases. Further, even when a database indexes the same journal, the citations may not all be indexed or tagged the same way (for example, there are different subject thesauruses in PubMed and CINAHL) or different field search options.

As we were interested in chronicling all of the available literature pertaining to poultry intake and human health, the search strategy did not include a filter for year published.

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CHAPTER 3: METHODS

Protocol and PRISMA-ScR checklist

The protocol for this scoping review was uploaded to Open Science Framework and was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) extension for scoping reviews (PRISMA-ScR) recommended guidelines for developing and reporting the evidence reviewed for this article¹. The PRISMA-ScR checklist for this scoping review is presented in the **Appendix**. This scoping review included observational articles, randomized controlled trials, review articles (including narrative and literature reviews), and systematic reviews and/or meta-analyses of observational articles or randomized controlled trials which assessed associations between or effects of, respectively, poultry intake on human health.

Identifying the research questions

What scientific literature currently exists that is pertinent to poultry intake and human health?

What are the current knowledge gaps and how could these be addressed?

Search strategy, article selection and data extraction

Potentially eligible articles were identified via a systematic search of four electronic health research databases (PubMed, Cochrane Library, CINAHL (EBSCO) and Scopus) from inception up to March 2020. The database search strategies were developed by a health sciences librarian (JBR) in collaboration with other review team members. The search was conducted on March 4th, 2020 and identified 19, 286 articles. After removing duplicates, there were a total of 13,145 articles. There were four total reviewers (AWB, CMC, GC and RECC) and each abstract was independently assessed using Rayyan by two different reviewers to determine eligibility. A fifth reviewer (WWC) was consulted if the four primary reviewers could not reach a consensus on article inclusion or exclusion. The reference lists of eligible articles were searched for additional articles which may fulfil the inclusion criteria. The inclusion and exclusion criteria are presented in **Table 1**.

Table 1: Inclusion and Exclusion Criteria

Included	Excluded
Any article that used a qualitative or quantitative design that assessed poultry intake and health outcomes in humans of all ages	Articles or articles not pertaining to human health
Published in the English language	Not published in the English language
Published up to March 2020	Grey literature
Both unprocessed and processed poultry products were within the scope of this review	Articles assessing dietary patterns and health outcomes without assessing poultry intake as an independent component
Articles assessing chicken essence intake and health outcomes were within the scope of this review	Articles assessing trends in poultry purchase correlated with trends in health outcomes. These were excluded as poultry purchasing is not synonymous with poultry consumption.
	Articles assessing “white meat” intake without defining “white meat”
	Articles with a definition of white meat that included rabbit or other non-poultry meats in the definition
	Articles that could not be accessed after contacting the authors

The search process and data extraction process consisted of the following three stages: 1) potential eligibility based on information provided in the title and abstract, 2) confirmation of eligibility based on information provided in the purpose statement of the full text of qualified abstracts, and 3) data extraction from full text articles if deemed qualified. The information extracted from all qualified full text articles is presented in **Table 2**.

Table 2: Data extracted from included articles

Data Extracted	Selections Designated <i>a priori</i> to Data Extraction
Author	N/A
Journal of publication	N/A
Year of publication	N/A
Geographical location of research	North America, South America, Europe, Eastern Asia, Western Asia, Africa, and/or Australia/New Zealand, or not Reported
General health outcome	Body composition, CVD, T2DM, cancer, and or/ other, or not reported
Specific health outcome	N/A
Purpose statement as reported by authors at the end of the introduction	N/A
Article Design	Observational-case control, observational-nested-case control, observational-cohort, observational-cross-sectional, acute feeding RCT, chronic feeding RCT, narrative or literature review, systematic review, meta-analysis without a systematic search (including data pooled from multiple articles), or meta-analysis with systematic search
Age of participants	Children, adults, and/or older (50+), or not reported
Sex of participants	Male, female, both, or not reported
Race and ethnicity of participants	White (Hispanic/Latino, not Hispanic/Latino), Asian, Black/African American, American Indian/Alaskan Native, Native Hawaiian/Other Pacific Islander, Not Reported
Health status of participants	Healthy, cancer, heart disease, brain disorders (including mental illness as well as cognitive health problems), diabetic, and/or other, or not reported
BMI status of participants	Underweight, normal weight, overweight, and/or obese, or not reported <i>Note: If the included range of BMIs of the population was not reported, the average BMI of the population was extracted</i>
Poultry intake as an priori independent variable or not	Yes, no
Description of type of poultry	Poultry, chicken, turkey and/or other, or not reported
Description of cooking method	Baked, grilled, barbecued, fried, and/or other, or not reported
Skin on poultry	Yes, no, or not reported
Comments	Indicated whether processed poultry was assessed, other relevant comments

The data from each article were independently extracted by two reviewers and crosschecked to ensure accuracy. Article authors were contacted for additional information if

required. Risk of bias for included articles was not assessed, and strength of evidence was not graded as the purpose of this scoping review was to systematically search and chronicle the body of existing searchable literature pertinent to poultry intake and human health and to identify knowledge gaps. The extracted data from each included article are presented in the **Appendix**.

The following abbreviations for article designs will be used henceforth:
OBS=observational, RCT=randomized controlled trial, NR/LR=narrative review/literature review, SR=systematic review, SR/MA=systematic review with meta-analysis, MA=meta-analysis without a systematic search, including meta-analyses of pooled studies.

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CHAPTER 4: RESULTS

A total of 540 articles that met the inclusion criteria were identified. The flowchart of study selection is presented in **Figure 1**.

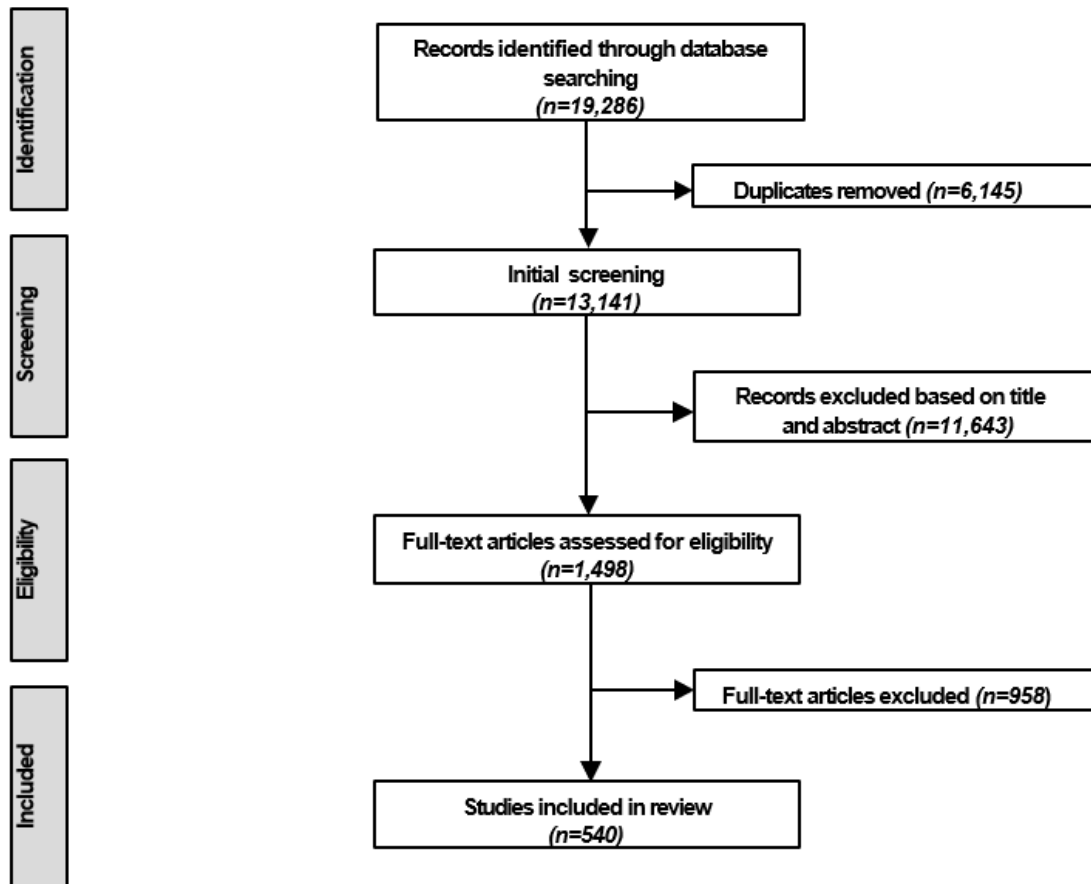


Figure 1: Flowchart of Screening Process for Inclusion

Most articles (92.0%) assessed poultry intake and health outcomes in adults and older populations. 8% were conducted in children, or the age of the population was not reported. The types of article designs and general health outcomes of the included articles are presented in **Table 3**. **Figure 2** reports a visual interpretation of the types of articles included.

Table 3: Article designs and health outcomes of included articles

	Body Composition	Cancer Risk Factors	Cancer Morbidity/Mortality	CVD Risk Factors	CVD Morbidity/Mortality	Diabetes Risk Factors	Diabetes Morbidity/Mortality	Other
Total Articles	42	22	212	52	41	33	32	181
OBS*	32	12	164	27	31	16	25	111
Case-Control	5	2	93	0	4	0	1	19
Nested Case-Control	0	1	7	1	2	0	1	1
Cohort	8	1	56	12	20	6	18	37
Cross-Sectional	19	8	8	14	5	10	5	54
RCT*	8	6	0	18	0	13	0	37
Acute Feeding	0	5	0	1	0	8	0	15
Chronic Feeding	8	1	0	17	0	5	0	22
NR/LR*	1	3	18	4	8	2	5	13
SR*	0	0	4	0	0	0	1	1
MA*	1	0	13	0	1	0	1	0
SR/MA*	0	0	10	3	1	2	0	3
Other	0	1	3	0	0	0	0	16

*OBS=observational, RCT=randomized controlled trials, NR/LR=narrative review/literature review, SR=systematic review, MA=non-systematically searched meta-analysis, SR/MA=systematically searched meta-analysis

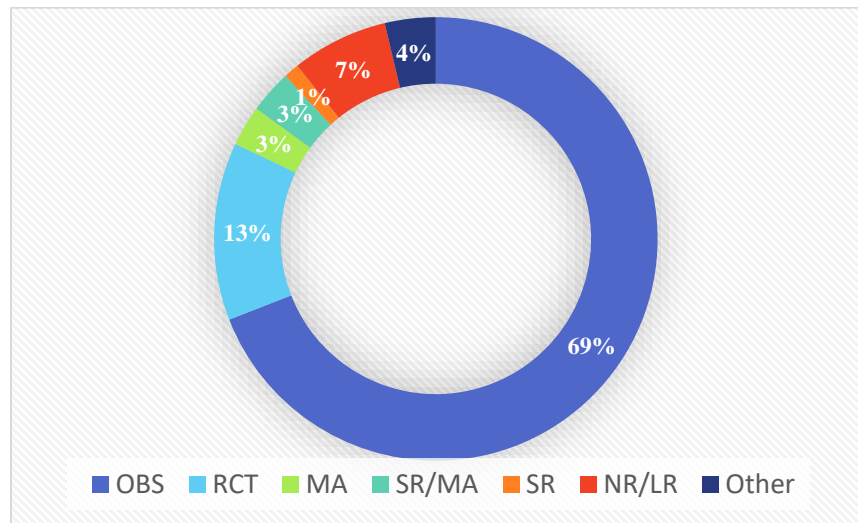


Figure 2: Visual representation of types of article designs included

Body composition

Forty-two articles investigated the relationship between poultry intake and body composition. The specific health outcomes for body composition were primarily body mass index (BMI) and other anthropometric measurements. A few articles assessed muscle and/or bone health. Thirty-two articles were OBS (5 case-control, 8 cohort, 19 cross-sectional) in design. Eight articles were chronic feeding RCTs. One NR/LR conducted in 2014 described the relationship between food intake and BMI among various Hawaiian ethnic groups. A 2006 MA examined the association between food and beverage groups and myriad health outcomes, including overweight and obesity. **Figure 3** reports the number of articles published per five-year interval beginning in 1970 for body composition as a health outcome assessed.

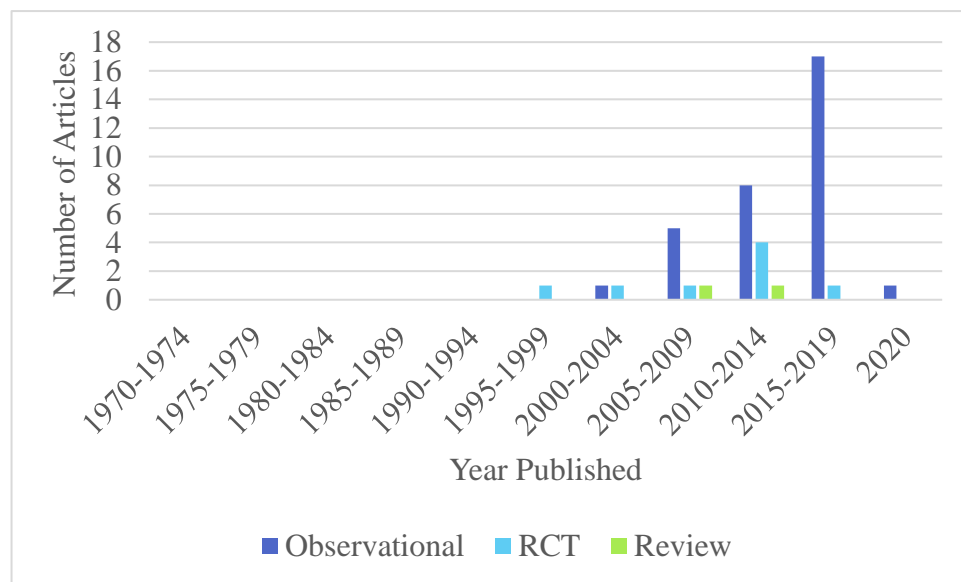


Figure 3: Articles published per five-year period assessing body composition

Cancer risk factors

Twenty-two articles examined the relationship between poultry intake and cancer risk factors. There were 12 OBS articles (2 case-control, 1 nested case-control, 1 cohort, and 8 cross-sectional). The OBS articles generally investigated exposure (both dietary and other environmental) to known carcinogens. There were 6 acute feeding RCTs which assessed the metabolism of carcinogenic compounds after the consumption of poultry products, and one chronic feeding RCT examining the relationship between usual diet and a low-fat diet and oxidative DNA damage in healthy women. Three NR/LRs have been published on this topic.

Figure 4 reports the number of articles published per five-year interval beginning in 1970 for cancer risk factors as a health outcome assessed.

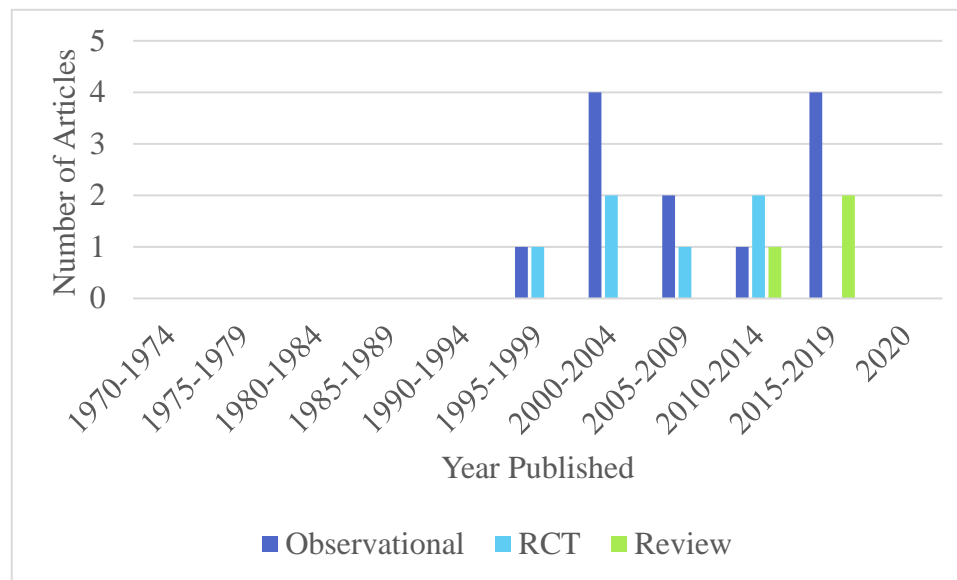


Figure 4: Articles published per five-year period assessing cancer risk factors

Cancer morbidity and mortality

Two hundred-twelve articles investigated the relationship between poultry intake and cancer morbidity and mortality. All primary literature articles (n=164) were OBS, conducted exclusively in adult and older populations. The majority (56.6%) were case-control in design (n=94), with 7 nested case-control, 56 cohort, and 9 cross-sectional articles. **Table 4** presents the number of primary articles identified by cancer subtype.

Table 4: Primary Articles by Cancer Subtype

Cancer Subtype	Number of Articles	Cancer Subtype	Number of Articles
Colorectal	40	Lymphoma	2
Breast	29	Rectal	2
Prostate	11	Non-Hodgkin Lymphoma	2
Pancreatic	10	Thyroid	2
Colon	9	Oral	2
Esophageal	9	Ovarian	2
Lung	9	Squamous Cell Carcinoma	1
Gastric	7	Unilateral Retinoblastoma	1
Bladder	6	Upper-aerodigestive	1
Endometrial	4	Biliary Tract	1
Leukemia	4	Brain	1
Liver	3	Head and Neck	1
Renal	3	Hypopharyngeal	1

Colorectal cancer was the most studied cancer subtype. One systematic review qualitatively assessed poultry consumption and colorectal cancer. Two Mas have been conducted (in 2013 and 2015) assessing poultry intake and colorectal cancer morbidity/mortality. Three SR/MAs have been performed, the latest in 2017.

SR/MAs have been conducted for several other cancer subtypes: endometrial cancer (2007), ovarian cancer (2010), esophageal cancer (2013 and 2014), hematological cancers (2019), breast cancer (2016), and lung cancer (2012).

MAs exist for non-Hodgkin lymphoma (2006), renal cancer (2007), prostate cancer (2016), esophageal cancer (2016), brain cancer (2019), pancreatic cancer (2012), and total cancer mortality (2017). SRs were conducted assessing poultry intake and esophageal cancer (2018) and prostate cancer (2014). A 2016 SR critically evaluated existing meta-analyses examining the relationship between meat consumption (including poultry) and cancer risk. **Figure 5** reports the

number of articles published per five-year interval beginning in 1970 for cancer morbidity/mortality as a health outcome assessed.

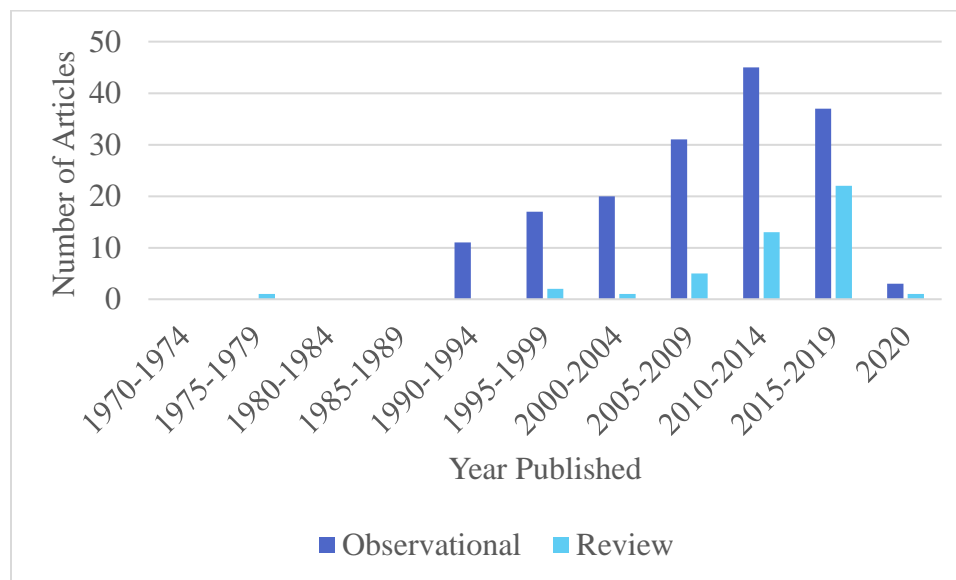


Figure 5: Articles published per five-year period assessing cancer morbidity/mortality

CVD risk factors

Fifty-two articles analyzed the relationship between poultry intake and CVD risk factors. Notable risk factors assessed were hypertension, metabolic syndrome, body composition, and lipid profiles, among others. There were 27 OBS articles (12 cohort, 1 nested case-control, and 14 cross-sectional in design). There were 1 acute feeding RCT and 17 chronic feeding RCTs identified. An SR/MA of RCTs examining CVD risk factors was conducted in 2019. SR/MAs were performed assessing the association between meat consumption and metabolic syndrome (2018) as well as hypertension (2018). **Figure 6** reports the number of articles published per five-year interval beginning in 1970 for CVD risk factors as a health outcome assessed.

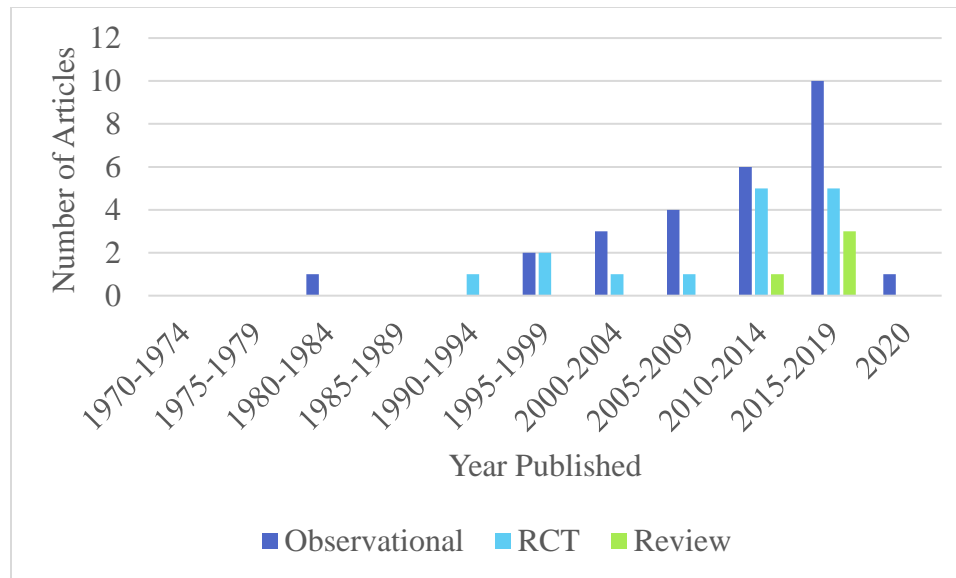


Figure 6: Articles published per five-year period assessing CVD risk factors

CVD morbidity and mortality

Forty-one articles assessed relations between poultry intake and CVD morbidity and mortality. The 31 OBS articles (4 case-control, 2 nested case-control, 20 cohort and 5 cross-sectional) assessed the impact of poultry consumption on risk of stroke, heart failure, acute myocardial infarction, ischemic heart disease, and coronary heart disease, among others. The majority were OBS cohort designs. Eight NR/LRs were identified pertaining to poultry intake and CVD outcomes. A 2018 MA assessed the relationship between poultry intake and stroke. **Figure 7** reports the number of articles published per five-year interval beginning in 1970 for CVD morbidity/mortality as a health outcome assessed.

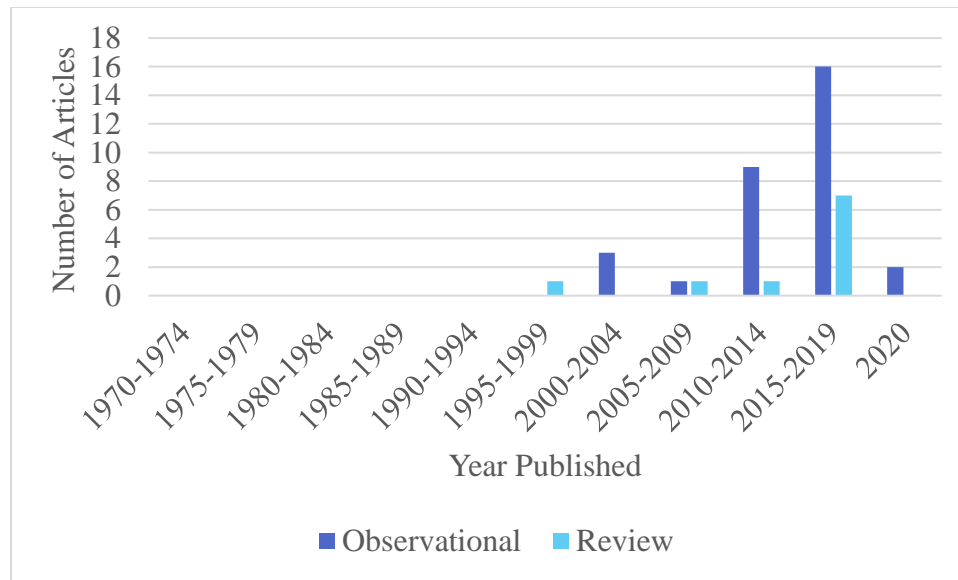


Figure 7: Articles published per five-year period assessing CVD morbidity/mortality

Diabetes risk factors

Thirty-three articles investigated poultry intake and diabetes risk factors. 16 OBS articles were identified, 6 cohort and 10 cross-sectional in design. OBS articles assessed BMI, C-reactive protein concentrations and advanced glycation end-product concentrations. Five chronic feeding RCTs were identified, examining the link between the impact of diets containing poultry on risk factors such as blood pressure and lipid profiles. The 8 identified acute feeding RCTs measured glycemic and insulineric responses to various foods, including poultry. **Figure 8** reports the number of articles published per five-year interval beginning in 1970 for diabetes risk factors as a health outcome assessed.

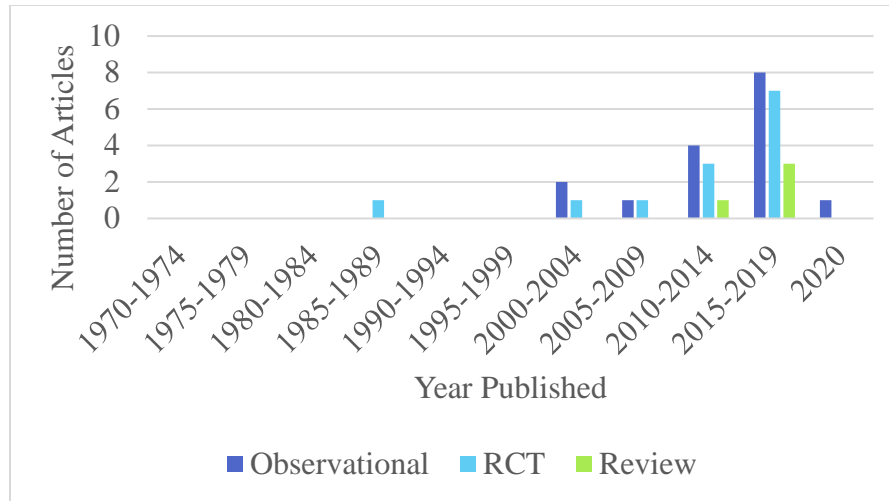


Figure 8: Articles published per five-year period assessing diabetes risk factors

Diabetes morbidity and mortality

Thirty-two articles assessed diabetes morbidity and mortality. The 25 primary articles were all OBS in design (1 case-control, 18 cohort, 5 cross-sectional, and 1 nested case-control). Twenty-two articles examined T2DM, and 3 assessed gestational diabetes. Four NR/LRs assessed the link between various food groups and T2DM, and one assessed high protein diets and diabetic kidney disease. A 2010 SR assessed food groups and the management of diabetes. A 2019 dose-response MA of prospective articles examined the relationship between dietary protein intake and diabetic morbidity. **Figure 9** reports the number of articles published per five-year interval beginning in 1970 for diabetes morbidity/mortality as a health outcome assessed.

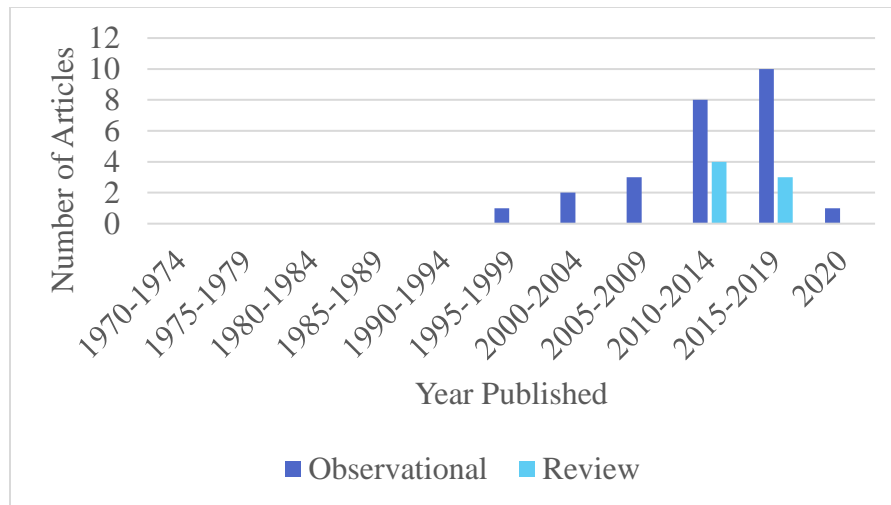


Figure 9: Articles published per five-year period assessing diabetes morbidity/mortality

Other health outcomes

The Other category contained 181 articles. The health outcomes examined in these articles included nutrient status, psychological well-being/mental health, cognitive outcomes, microbiome outcomes, chronic kidney disease (CKD), non-alcoholic fatty liver disease (NAFLD), skin disorders, and fertility, among others. Fifteen acute feeding RCTs fell into this category, assessing appetite and satiety, mood, and renal hemodynamics, among others. Twenty-one chronic feeding RCTs were identified, covering a broad range of health outcomes including cognitive function, microbiome and nutrient status. There were 16 articles that were classified as “other” in design, as they did not fit the criteria for the other article design types. Many of these were case articles, or a summary of medical treatments. Several articles assessed poultry intake and food-protein induced enterocolitis syndrome (FPIES) in infants. Thirteen NR/LRs were identified. Three examined the link between poultry consumption and FPIES, and two assessed fertility (both male and female). The other NR/LRs assessed the relationship between poultry consumption and BMI, NAFLD, CKD, general health status, diabetic kidney disease, diverticulitis, and health burden. Three SR/MAs exist for chicken essence intake and cognitive function. One SR was conducted assessing components of diet and male fertility. **Figure 10** reports the number of articles published per five-year interval beginning in 1970 for Other health outcomes assessed.

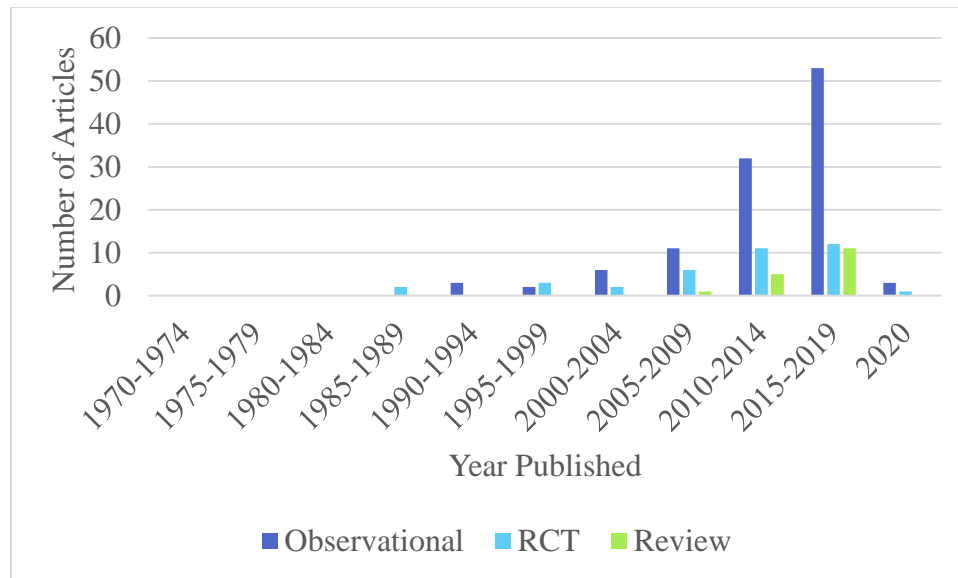


Figure 10: Articles published per five-year period assessing other health outcomes

Assessments of processed poultry and health outcomes

A total of four OBS articles (of 371) assessed the influence of processed poultry on health outcomes (**Figure 11**). This does not include articles with a definition of poultry that may have included processed poultry in the assessment of poultry and health outcomes. Of 70 identified RCTs assessing poultry intake and health outcomes, zero included assessments of processed poultry intake (**Figure 12**).

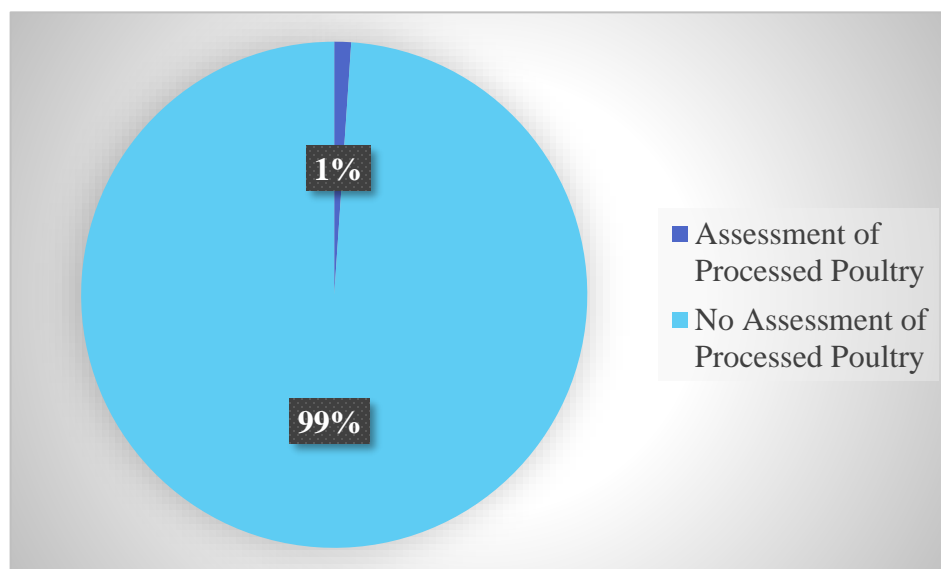


Figure 11: OBS article assessing processed poultry and health outcomes

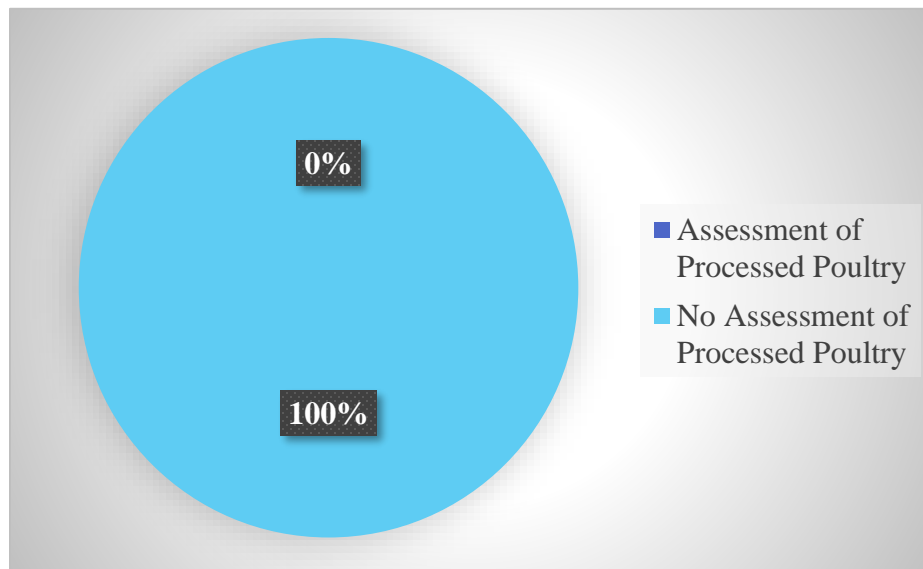


Figure 12: RCT articles assessing processed poultry and health outcomes

Reporting of cooking methods

Of the 371 identified OBS articles, 54 reported on cooking methods of the poultry included in assessments (**Figure 13**). A slight majority of RCT articles did not report on cooking methods for poultry used in trials (**Figure 14**). **Figure 15** presents the proportion of RCTs assessing chicken essence versus poultry meat.

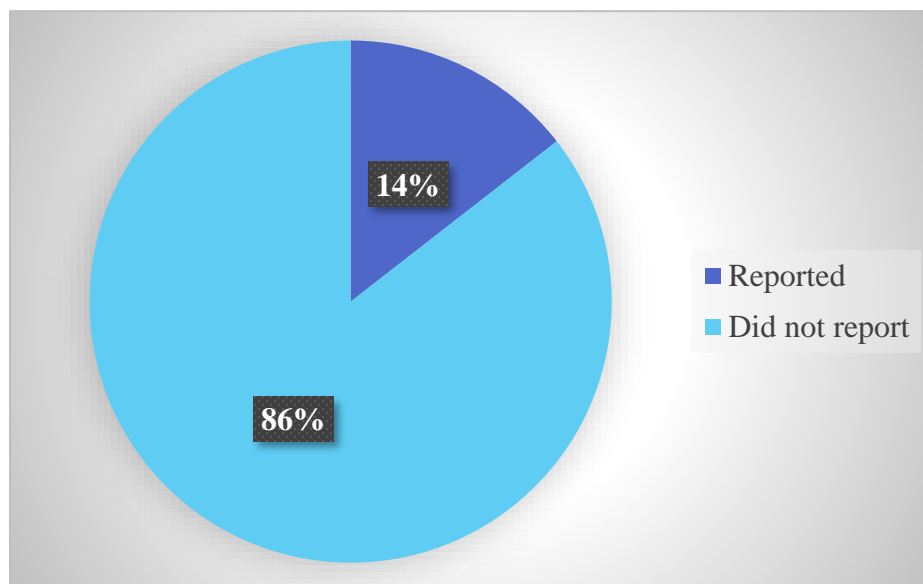


Figure 13: OBS articles that reported on poultry cooking method

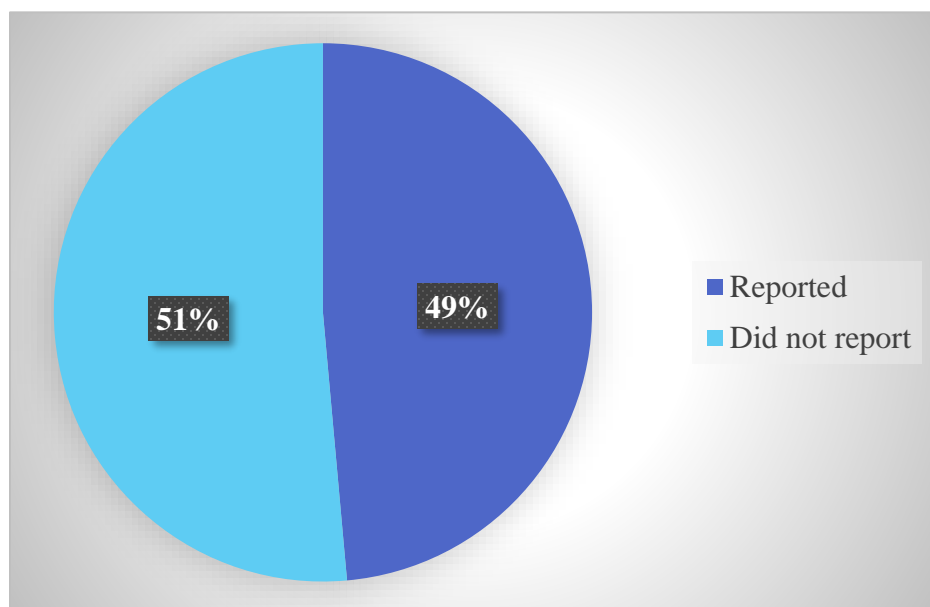


Figure 14: RCT articles that reported on poultry cooking method

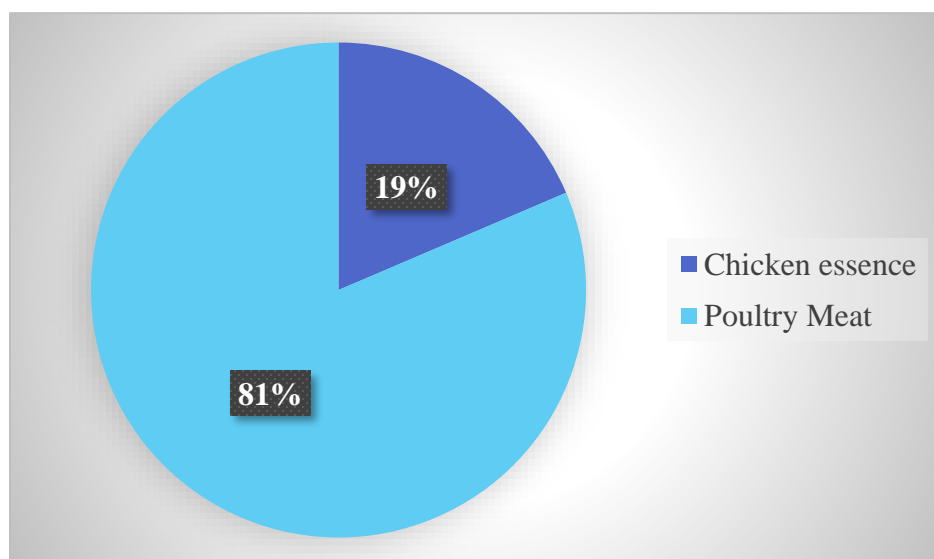


Figure 15: Proportion of RCTs assessing chicken essence versus poultry meat

CHAPTER 5: DISCUSSION AND FUTURE DIRECTIONS

To the best of the authors' knowledge, this was the first scoping review to systematically search scientific literature to chronicle published literature pertinent to poultry intake and human health. This scoping review followed a rigorous process and conducted the search and review according to PRISMA-ScR guidelines. In addition, the comprehensive search capturing current scientific literature regarding poultry and all facets of human health is particularly noteworthy. By gathering searchable literature, this review paved a path for future systematic reviews and analyses and highlights areas where more research is needed.

Lack of assessment of poultry processing in human health

1% of OBS articles assessed relations between processed poultry consumption and human health-related parameters. As indicated above, processed poultry differs from fresh poultry in sodium content, preservative addition, and sometimes macronutrient composition if fats are added. Independently assessing its influences on human health in OBS studies would be helpful for the scientific community, as well as consumers, to be better informed on the potential link between processed poultry products and adverse health outcomes.

Additionally, there are no RCTs assessing processed poultry intake and human health outcomes. Processed poultry can contain higher levels of sodium as well as other ingredients implicated in adverse health outcomes, like the addition of sodium nitrate and sodium nitrite as preservatives. Human clinical studies assessing processed poultry intake are warranted, as this is a highly consumed food product in the U.S.

Lack of reporting of cooking methods

There was a lack of reporting on cooking methods in both RCTs and OBS articles. 51% of RCTs did not provide information regarding cooking methods of the poultry consumed by participants. Moreover, only 14% of OBS articles provided any information regarding the cooking methods of poultry in their assessments. Cooking method is an important consideration, as meats cooked at a high temperature associate with adverse health outcomes, most notably cancer. This is due to the formation of potentially carcinogenic heterocyclic amines (HCAs) and

polycyclic aromatic hydrocarbons (PAHs). HAAs are formed as the reaction of free amino acids, sugar, and creatine or creatinine². PAHs are formed from fats or meat juices dripping onto an open flame and are then transferred through smoke to the surface of the meat product². Thus, it is of importance to consider cooking method when assessing meat intake, including poultry, as a boiled chicken breast may contain much lower concentrations of potential carcinogens as a grilled chicken thigh.

Future directions

Chronic feeding RCTs are warranted assessing fresh versus processed poultry products on cardiometabolic health outcomes as well as cancer risk factors (the presence of carcinogenic metabolites as a result of dietary exposure). The higher sodium content, as well as potentially higher fat content, of processed poultry could have a deleterious effect on cardiometabolic health. There have been acute feeding RCTs assessing poultry intake (fresh poultry cooked at high temperatures) and metabolism of carcinogens, but a chronic feeding study would be helpful to determine if consumption of processed poultry products leads to an increase in carcinogenic metabolites compared to fresh poultry. Djuric et al. (1998) assessed oxidative damage in women fed either a low-fat diet or their usual diet³; a similar study design could be employed for this research question.

The scientific community and poultry stakeholders could benefit from systematic reviews on several health outcomes as well. The relationship between poultry consumption and body mass index has been assessed in primary literature; 23 OBS studies examine the relation between poultry intake and BMI or overweight/obesity in adult populations. Likewise, there is no systematically searched review on poultry consumption and cancer risk factors, though 10 OBS articles and 4 RCTs exist on this topic. A systematic review assessing poultry intake in CVD morbidity and mortality is notably absent; there is an MA and an SR/MA assessing poultry intake and stroke, but not for other CVD outcomes. Four OBS articles assess poultry intake and risk of acute myocardial infarction, 3 assess coronary heart disease, 2 assess peripheral arterial disease, and 8 assess CVD mortality. An SR/MA of the role of poultry intake in T2DM morbidity is merited. A 2019 MA examined only prospective studies, but one including other OBS study designs would be helpful to fully chronicle the current literature on this health outcome. Additionally, SR/MAs exist for hypertension and metabolic syndrome, but a SR

including all T2DM risk factors does not exist. There are 7 acute feeding RCTs assessing glycemic and insulinemic responses to meals including poultry; these could be used alongside OBS studies examining T2DM incidence using the Bradford-Hill causality model to assess a causal role of poultry intake in development of T2DM.

Conclusion

This scoping review systematically identified scientific literature pertinent to poultry intake and all facets of human health. It provided the types of article designs that exist for each designated health outcome, as well as the years in which research was published by health outcome. This review also highlighted areas where poultry research is apparently lacking. The influences of processed poultry in human health outcomes should be assessed, and cooking methods of poultry should be reported in both RCTs and OBS articles to understand the role of poultry more completely in human health outcomes. This review also provided suggestions for potential RCTs that would help to elucidate the effects of consuming fresh versus processed poultry products on cardiometabolic and cancer risk factor outcomes. Additionally, this review gave guidance on where systematic reviews assessing poultry intake and the following health outcomes are warranted: body mass index/overweight/obesity, CVD morbidity and mortality, and T2DM risk factors and morbidity.

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APPENDIX

Table 1: PRISMA-ScR Checklist for this scoping review

SECTION	PRISMA-ScR CHECKLIST ITEM
TITLE	
Title	Poultry Intake and Health Outcomes: A Scoping Review of the Literature
ABSTRACT	
Structured summary	TBD
INTRODUCTION	
Rationale	Chicken meat, the predominant type of poultry consumed in America, is central to providing high-quality protein and other nutrients and is generally considered a “healthy” meat. Research articles have included assessments of how chicken/poultry influences various facets of human health, but systematic searching of literature designed to chronicle this research is apparently lacking.
Objectives	The purpose of the scoping review is to systematically search scientific literature to chronicle the body of existing literature pertinent to chicken/poultry intake and human health and to identify knowledge gaps. We are interested in determining the existence of literature regarding poultry intake and its influence on (but not limited to): Body Weight/Composition, Cardiovascular Disease (CVD), Type II Diabetes (T2D), and Cancer. We will include both observational articles and randomized controlled trials as well as reviews, systematic reviews and meta-analyses in humans.
METHODS	
Protocol and registration	The protocol has been uploaded to the Open Science Framework (OSF).
Eligibility criteria	Methodological Quality: Primary research articles (RCT, observational articles) and reviews Linguistic Range: English Article Population: All humans (male and female) of all ages, any race and geographical location Grey literature and articles not in the English language will be excluded
Information sources*	PubMed, Cochrane, Scopus and CINAHL

Search	<p>PubMed Search run March 4th 2020 8,320 total results Filters applied: English language</p> <p>poultry[Title/Abstract] OR "white meat"[Title/Abstract] OR chicken[Title/Abstract] OR duck[Title/Abstract] OR turkey[Title/Abstract] OR quail[Title/Abstract] OR pheasant[Title/Abstract] OR ostrich[Title/Abstract] OR "Poultry"[Mesh]</p> <p>AND</p> <p>"Feeding Behavior"[Mesh] OR "Diet"[Mesh] OR "Eating"[Mesh] OR consum*[Title/Abstract] OR cooked[Title/Abstract] OR cooks[Title/Abstract] OR cook[Title/Abstract] OR diet[Title/Abstract] OR diets[Title/Abstract] OR dietary[Title/Abstract] OR eat[Title/Abstract] OR eats[Title/Abstract] OR eater[Title/Abstract] OR eating[Title/Abstract] OR intake[Title/Abstract] OR intakes[Title/Abstract]</p> <p>NOT ("Animals"[Mesh] NOT ("Animals"[Mesh] AND "Humans"[Mesh]))</p> <p>Cochrane Search Run March 4th 2020 995 Trials and 14 Reviews No filters applied (language was not an option)</p> <p>(Poultry OR "white meat" OR chicken OR duck OR turkey OR quail OR pheasant OR ostrich):ti,ab,kw OR poultry[mesh]</p> <p>AND</p> <p>(consum* OR cooked OR cooks OR cook OR diet OR diets OR dietary OR eat OR eats OR eater OR eating OR intake OR intakes):ti,ab,kw OR "Feeding Behavior"[Mesh] OR "Diet"[Mesh] OR "Eating"[Mesh]</p> <p>Scopus Search run March 4th 2020 7,686 total results Filters included in search string (LIMIT-TO)</p> <p>(TITLE-ABS-KEY (consum* OR cooked OR cooks OR cook OR diet OR diets OR dietary OR eat OR eats OR eater OR eating OR intake OR intakes)) AND (TITLE-ABS-KEY (poultry OR "white meat" OR chicken OR duck OR turkey OR quail OR pheasant OR ostrich)) AND (TITLE-ABS-KEY (human OR humans OR adolescent OR adolescents OR teens OR teenager OR teenagers OR adult OR adults OR child OR children)) AND (LIMIT-TO (SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "NURS") OR LIMIT-TO (SUBJAREA , "MULT") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO (SUBJAREA , "NEUR")) AND (LIMIT-TO (LANGUAGE , "English"))</p> <p>Scopus 7,152 (Can get it down to ~3000 by excluding subject areas. ((TITLE-ABS-KEY (poultry OR "white meat" OR chicken OR duck OR turkey OR quail OR pheasant OR ostrich) AND TITLE-ABS-KEY (consum* OR cooked OR cooks OR cook OR diet OR diets OR dietary OR eat O</p>
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	<p>R eats OR eater OR eating OR intake OR intakes)) AND (TITLE-ABS-KEY (human OR humans OR adolescent OR adolescents OR teens OR teenager OR teenagers OR adult OR adults OR child OR children)) AND (LIMIT-TO (SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "NURS") OR LIMIT-TO (SUBJAREA , "HEAL")) AND (LIMIT-TO (LANGUAGE , "English"))</p> <p>CINAHL Search run March 4th 2020 Total results: 2,271 Filters applied: English Language, journal articles</p> <p>(MH "Poultry") OR TI (poultry OR "white meat" OR chicken OR duck OR turkey OR quail OR pheasant OR ostrich) OR AB (poultry OR "white meat" OR chicken OR duck OR turkey OR quail OR pheasant OR ostrich) OR MW (poultry OR "white meat" OR chicken OR duck OR turkey OR quail OR pheasant OR ostrich)</p> <p>AND</p> <p>(MH "Diet+") OR (MH "Eating Behavior+") OR (MH "Eating") OR TI (consum* OR cooked OR cooks OR cook OR diet OR diets OR dietary OR eat OR eats OR eater OR eating OR intake OR intakes) OR AB (consum* OR cooked OR cooks OR cook OR diet OR diets OR dietary OR eat OR eats OR eater OR eating OR intake OR intakes) OR MW (consum* OR cooked OR cooks OR cook OR diet OR diets OR dietary OR eat OR eats OR eater OR eating OR intake OR intakes)</p>
Selection of sources of evidence†	<p>Abstract review</p> <p>The initial review of title and abstracts will be screened independently by two reviewers (CC and GC). Cases where it is unclear if the article is a primary research article will be included at this stage for further analysis in the full-text review.</p> <p>Full text review to determine whether to determine whether the article meets the inclusion criteria. Authors will be contacted for more information if required.</p>
Data charting process‡	Utilize a spreadsheet created prior to data extraction; extracted data will be second-person verified.
Data items	Population, geographical location, # of participants, type of article, age, poultry as a priori independent variable or not, health outcome(s), description of type of poultry (chicken or turkey, breast, thigh, etc), description of cooking method (baked, fried, etc.), processed or unprocessed, general conclusion of article, odds ratio (OR) or relative risk (RR) if analyzed.
Critical appraisal of individual sources of evidence§	N/A for our purpose

Synthesis of results	Describe the methods of handling and summarizing the data that were charted.
RESULTS	
Selection of sources of evidence	The searches returned 19,286 articles in total. The total after removing duplicates was 13,145 articles. The 13,145 articles were screened for inclusion based on the inclusion and exclusion criteria.
Characteristics of sources of evidence	For each source of evidence, present characteristics for which data were charted and provide the citations.
Critical appraisal within sources of evidence	If done, present data on critical appraisal of included sources of evidence (see item 12).
Results of individual sources of evidence	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.
Synthesis of results	Summarize and/or present the charting results as they relate to the review questions and objectives.
DISCUSSION	
Summary of evidence	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.
Limitations	Discuss the limitations of the scoping review process.
Conclusions	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.
FUNDING	
Funding	This scoping review was funded by the National Chicken Council (NCC). +A12:B30A9:B30A8:B30A5:B30A3:B30A2:B30A1:B30B11A15:B30A2:B30A3:B30A2:B30A1:B30

VITA

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Provided technical support for several randomized controlled trials in humans, including recruitment, performing anthropometric and other measurements, processing blood and processing fecal samples for microbiome assessment.

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Provided manufacturing support in a primary loop role. Investigated deviations that occurred during manufacturing, and provided rationale for the future of drug batches in which deviations occurred. Updated the manufacturing batch record tickets as needed. Worked closely with manufacturing operators and process team for continuous improvement in process control and manufacturing efficiency.

Publications

1. O'Connor LE, Kim JE, Clark CM, Zhu W, Campbell WW. Effects of Total Red Meat Intake on Glycemic Control and Inflammatory Biomarkers: A Meta-Analysis of Randomized Controlled Trials. *Adv Nutr.* 2021;12(1):115-127. doi:10.1093/advances/nmaa096
2. O'Connor L, Kim JE, Zhu W, Clark C, Campbell W. Effects of Total Red Meat Consumption on Glycemic Control and Inflammation: A Systematically Searched Meta-analysis and Meta-regression of Randomized Controlled Trials (OR22-08-19). *Current Developments in Nutrition.* 2019;3(Supplement_1). doi:10.1093/cdn/nzz028.or22-08-19

Ongoing Research

Randomized Controlled Trials

- Effects of red meat and processed meat consumption on gut microbiota in young adults
- Article on gut health and consumption of foods from animals raised with antimicrobial medications

Systematic Reviews, Meta-Analyses and Narrative Reviews

- Red Meat Intake and Cardiometabolic Disease Risk: An Assessment of Causality Using The Bradford Hill Criteria
- Red Meat Intake and Cancer Risk: An Assessment of Causality Using The Bradford Hill Criteria
- Poultry Intake and Human Health: A Narrative Review
- Effects of Meat Consumption on the Microbiome

Other

- Provided technical support to associates at Johns Hopkins by freeze-drying beef for animal study