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Unveiling the Dual Effect of Red Meat on Cancer Prevention & Progression: A Scientific Scoping Review

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Abstract: Background: Colorectal cancer is a serious health problem worldwide, with diet playing a big role in its development. Studies often connect eating red meat, processed kinds to a higher chance of getting this cancer. Yet, the link between red meat and CRC is not clear-cut. Some research points to elements in red meat that might help protect against the disease. Objective: This review looks at how red meat might both raise and lower the risk of colorectal cancer by examining evidence about its harmful and helpful effects. Methods: Researchers combined findings from many studies on how eating red meat impacts cancer risk focusing on colorectal cancer. They looked at different types of red meat, like processed versus unprocessed as well as harmful substances such as N-nitroso compounds and heterocyclic amines, which form during meat processing or cooking at high temperatures. They also considered beneficial elements in red meat. Factors like cooking methods and genetics were reviewed to explore how they might change the overall risk. The study also reviewed the global advice on meat consumption and the rationale behind such advice. Results: Many studies have illustrated the relationship between high consumption of red meat-processed types and an increased incidence of colorectal cancer. [1] Carcinogenic agents such as N-nitroso compounds and heterocyclic amines, which are formed during the processing of meat and during cooking at high temperatures, are the major offenders. However, some data suggests unprocessed red meat in low amounts may not increase cancer risk, and components like conjugated linoleic acid or certain vitamins could provide some benefits. Evidence to support these benefits is limited, and further research is needed. Current dietary guidelines recommend decreasing intake of red and processed meat to reduce the risk of cancer, but still acknowledge red meat's nutritional benefits. Conclusion: High amounts of red meat especially processed kinds appear to be linked to a greater chance of colorectal cancer. [1] While red meat does contain elements that might offer protective effects, these findings are not strong enough to rely on. Public health experts recommend cutting back on red meat processed varieties, to help prevent colorectal cancer. Fruits and vegetables rich in vitamin C also contain a variety of other beneficial phytochemicals, antioxidants, and fiber that may synergistically contribute to cancer prevention. The use of combined

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vitamin A, C, and E supplements showed an association with a decreased risk of colon polyps; vitamin C protects against the risk of colorectal cancer.

Keywords: *Red Meat, Colorectal Cancer, Processed Meat, Meta-Analysis, Carcinogenesis, Cancer Prevention, N-Nitroso Compounds, Heterocyclic Amines, Conjugated Linoleic Acid, Dietary Guidelines.*

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I. INTRODUCTION

Meat is a valuable component of diet for the majority of people of the world, with red meat, in particular, providing a concentration of high-quality protein and important micronutrients, such as iron, zinc and vitamin B12. With increasing standard of living, the consumption of meat especially in the developing world has shown a substantial increase, highlighting the need of understanding its impact on human health. And yet, it's not as if the scientific community is in agreement here regarding red meat intake and cancer. Despite decades of evidence that have linked meat consumption to a variety of cancer type [2, 3], inconsistencies regarding study design, types of cancer examined and definitions of meat consumption used have led to these controversies. Complicating matters is the fact that there is an International Agency for Research on Cancer (IARC) grouping that has grouped processed meat into the "carcinogenic to humans" (Group 1) and red meat as "possibly carcinogenic to humans" (Group 2A) [4]. While such categorizations reflect potential harm, it is essential to identify that they are based upon the strength of the evidence and not necessarily the absoluteness of the risk. The variations between studies and the nuances of the classifications, argue the need of a systematic and critical appraisal of the existing evidence.

Scientists have suggested several ways that eating red meat might raise cancer risk. One major reason is heme iron, which is found in large amounts in red meat. In the digestive system heme iron may spark free radical production. These free radicals can harm DNA and help create carcinogenic substances known as N-nitroso compounds. Both red and processed meats can lead to N-nitroso compounds formation during digestion. Processed meats, which often contain nitrate and nitrite preservatives, may add to how these harmful compounds are created. These substances have been linked to damage in the cells lining the gut increasing the chances of colorectal cancer. [6,7,8]

Cooking red meat at very high temperatures like grilling or frying can generate harmful chemicals called heterocyclic amines (HCAs) and polycyclic aromatic hydrocarbons (PAHs). [9] These chemicals are known to alter DNA in ways that can push the chances of getting cancer higher. New research points to red meat's role in sparking chronic inflammation and changes in gut bacteria that might favour cancer development. Eating a lot of red meat can raise the number of gut microbes that stir inflammation.

Recent studies have focused on trans-vaccenic acid (TVA), a type of fatty acid in meat and dairy products from grazing animals, due to its role in helping CD8+ T cells to fight tumours better. This points to a possibility that a certain nutrient in red meat might play a part in cancer prevention or treatment. However, the overall effect of eating red meat on cancer risk seems linked to its cancer-causing compounds or the harmful byproducts created during its processing and cooking.

II. MATERIALS AND METHODS

This review used standard rules to carry out both systematic reviews and meta-analyses.

- *Information Sources*

The following electronic databases were searched from the time of their conception until 2025, in compliance with PRISMA guidelines: PubMed, Cochrane, and Embase.

- *Search Strategy*

Researcher searched key databases like PubMed, Embase, and the Cochrane Library to find studies linking red meat intake with cancer risk. Their search plan used various terms to look at "red meat," "processed meat," and particular cancers such as "colorectal cancer" or "gastric cancer".

- *Inclusion Criteria*

Research was included when it met specific criteria. These included being prospective cohort studies, meta-analyses, or case-control studies. It also needed to be published in peer-reviewed journals. Studies had to report numerical data linking red meat consumption to cancer risk. They considered human participants.

- *Exclusion Criteria*

Studies were excluded if they were reviews, editorials, or done on animals. They also excluded studies which were not in English or without enough data to analyse.

III. METHODOLOGY

Two independent reviewers handled data extraction. They pulled details like study features (author, publication year, study type, and population), sample size, and descriptions of participants from each selected study. They also noted how red meat consumption was assessed such as using diet

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questionnaires, along with cancer results, relative risks or hazard ratios, and their confidence intervals. Methods of cooking and any possible confounding factors included in the analysis were also recorded. They used accepted tools, like the Newcastle-Ottawa Scale, to examine the quality of the included cohort and case-control studies.

Researchers combined data using meta-analysis when it was possible. They focused on the link between red meat and cancer risk as the main outcome. They grouped the results by factors like types of red meat such as processed or unprocessed specific cancer types, and cooking methods. A random-effects model brought together the data from different studies. They used the I2 statistic to check for variability among the studies. Funnel plots and statistical methods helped them look for publication bias. The review followed a systematic plan to gather evidence on how eating red meat could affect cancer risk. The methods aimed to reduce errors and produce solid and trustworthy results.

IV. RESULTS

This research resulted in 45 articles, of which 7 were full-text articles having accessibility and were eligible for review. Ultimately those 7 articles were chosen for inclusion in this systematic review [Figure 1].

Table 1 shows the Characteristics of the studies included in the systematic review with Author name, samples recruited, sample characteristics, duration of the study and sample allocation.

Table 2 Shows the intervention used in the study included with the outcome.

Table 3 shows the risk of bias in all the included studies based on the Office of Health Assessment and Translation assessment tool. [22,23]

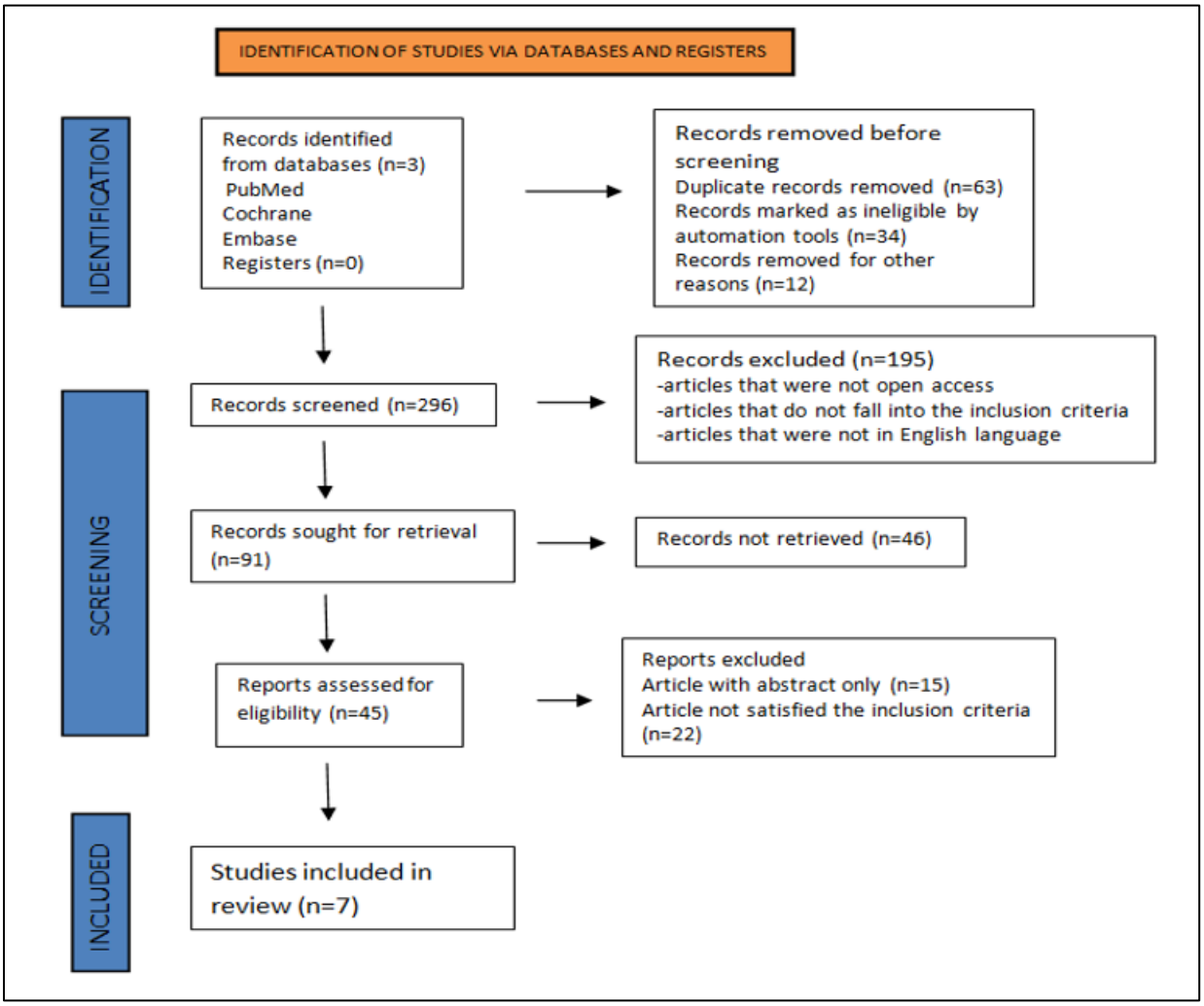

Fig 1 PRISMA Flow Diagram for Recently Conducted Systemic Reviews that Solely Involved Database and Registration Searches

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Table 1: Characteristics of Studies Included in the Systematic Reviews on Red Meat and Cancer Risk

Author/Study Focus	Year	Place of Study/Focus	Intervention	Study design
Kim et al. 2020	2020	Meta-analysis: Effect of red, processed, and white meat consumption on gastric cancer risk.	Red, processed, and white meat consumption.	Meta-analysis of prospective cohort studies.
Wolk A. 2017	2017	Review: Potential health hazards of eating red meat (including various cancers).	Red meat consumption and its association with chronic diseases, including cancer.	Review of accumulated evidence.
Aykan N.F. 2015	2015	Review: Red meat and colorectal cancer.	Red meat consumption and CRC risk.	Meta-analyses of prospective epidemiological studies.
Sivasubramanian et al. 2023	2023	Comprehensive Review of Red Meat Consumption and the Risk of Cancer	Red meat consumption	Review
Di et al. 2023	2023	Systematic review and meta-analysis: Association of meat consumption with gastrointestinal cancers.	Meat consumption and gastrointestinal cancers.	Systematic review and meta-analysis.
Islam et al. 2019	2019	Pooled analysis of 6 cohort studies in Japan: Meat subtypes and colorectal cancer risk.	Red meat subtypes	Pooled analysis of cohort studies.
Di Maso et al. 2013	2013	Network of case-control studies: Red meat and cancer risk focusing on cooking practices.	Red meat consumption and cooking practices	Analysis of data from a network of case-control studies.

Table 2: Summary of Findings from Systematic Reviews and Meta-Analyses

Study (First Author, Year)	Cancer Site	Red Meat Consumption	Relative Risk/Hazard Ratio (95% CI)	Key Findings/Comments
Kim et al., 2020	Gastric	High intake	Increased risk (Specific values vary across subgroups)	Meta-analysis; focus on gastric cancer
Wolk A., 2017	Multiple (including colorectal)	High intake	Increased risk (Specific values vary across cancers)	Review; broad overview of health hazards
Aykan N.F., 2015	Colorectal	High intake, especially processed	Increased risk (Convincing association)	Review; focus on colorectal cancer
Sivasubramanian et al., 2023	Multiple	High intake	Increased risk	Comprehensive Review

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Di et al., 2023	Gastrointestinal	High intake	Increased risk for CRC	Systematic review and meta-analysis
Islam et al., 2019	Colorectal	High intake of specific subtypes	Increased risk	Pooled analysis of cohort studies in Japan
Di Maso et al., 2013	Multiple	High intake, certain cooking methods	Increased risk (Influenced by cooking)	Case-control studies; focus on cooking practices

Table 3: Quality Assessment of All the Included Studies

Author Name	Randomization	Allocation Concealment	Comparison Group	Confounding	Experimental Conditions	Blinding	Complete Outcome Data	Exposure Characterization	Outcome Assessment	Outcome Reporting	No Other Threats
Kim et al., 2020											
Wolk A., 2017											
Aykan N.F., 2015											
Sivasubramanian et al., 2023											
Di et al., 2023											
Islam et al., 2019											
Di Maso et al., 2013											

Risk of Bias	Definitely Low Risk of Bias	Probably Low Risk of Bias	Probably High Risk of Bias	Definitely High Risk of Bias
Colour				

Table 3 shows the Risk of bias in all the included studies based on the Office of Health Assessment and Translation (OHAT) Assessment tool [20,21]

V. DISCUSSION

This systematic review has synthesized an extensive body of literature on the complex interplay of risk and protective factors between red meat consumption and cancer. The worries brought up by earlier research linking high consumption of red meat and processed meats, to a higher risk of various cancer types appear to have been backed up. Yet, there still doesn't seem

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to be much proof supporting the idea that it protects against cancer, which calls for more study. Apart from that, colorectal cancer stands out prominently as being connected with high red meat consumption in a number of studies. Such existence is also plausible from a biological standpoint, with different mechanisms proposed. [8, 11] The heme iron richly found in red meat catalyzes the formation of free radicals and carcinogenic N-nitroso compounds within the gut, whose effect in DNA damage has been fairly recognized. Also, the generation of heterocyclic amines (HCAs) and polycyclic aromatic hydrocarbons (PAHs) during grilling and frying direct the way for potent carcinogens to alter DNA structure, which is a rate-limiting step in cancer initiation. An emerging research trend suggests that the ingestion of red meat is potentially carcinogenic by promoting chronic low-grade inflammation and by causing dysbiosis of the gut microbiome. While colorectal cancer may have had the strongest association with red meat, this review also points to positive associations between red meat intake and breast, prostate, pancreatic, gastric, lung, endometrial, and renal cell cancer. [2, 4] Despite this, the strength and consistency of the evidence for these cancer types can greatly vary, with some of the associations not considered definitive and perhaps confounded by other factors.

Preeminent is the differentiation between processed and unprocessed red meat. Commonly the processed meat consumption is seen to predispose to a stronger cancer risk, with colorectal cancer in particular. Probably the addition of nitrates and nitrites in the processing procedure which may give rise to the formation of N-nitroso compounds has contributed to this risk. Cooking of red meat itself contributes to the risk factor. Cooking at very high temperatures, such as grilling, barbecuing, and pan-frying, may be conducive to the formation of HCAs and PAHs with the potential of DNA damage and carcinogenesis. [15]

Also, the presence of a dose-response relationship for most cancer types suggests an increased risk with higher quantities and more frequent consumption of red and processed meats. The World Cancer Research Fund and similar groups recommend limiting red meat and eating processed meat. [8]. Red meat provides important nutrients like omega-3s, selenium, vitamin B12, CLA, and zinc. Some recent studies suggest that trans-vaccenic acid (TVA) might help boost anti-tumor immunity. However, there is not enough evidence to confirm that red meat protects against cancer overall.[25] The putative advantages that these elements could confer might be overridden by the carcinogenic actions of other co-existing compounds or might only come to effect in a given diet-agent context.

One must take into consideration the limitations inherent in much of the evidence derived from observational studies. One should take into consideration the limitations inherent in much of the evidence derived from observational studies. Dietary and life-style confounders do impart their influence on the associations observed. The fact that inconsistencies arise for some cancers from one study to another underlines only the need to conduct further prospective studies under rigorous control of such confounding factors. [17] Another consideration is that susceptibility to the carcinogenic effects of red meat might be influenced by genetics. We must recognize the constraints of observational studies, which make up most of the evidence. Diet and lifestyle factors can affect the links we see. The differences we notice across studies for some cancer types show we need better future research that controls these factors. Also, genes might affect how red meat impacts a person's cancer risk. [16, 19]

Red meat's nutrients play two roles. They give us important nutrients like iron, which we need to stay healthy, but heme iron can also help cancer grow. Red meat has fats, including some that might be good for us, but cancer-causing compounds seem to have a stronger effect on cancer risk. What we eat overall, including foods that protect us like fruits, veggies, and whole grains likely changes how red meat affects our cancer risk [11].

This review strengthens the link between eating lots of red meat, processed meat, and a higher chance of getting several cancers, with colon cancer being the most common. The way heme iron, N-nitroso compounds, and cancer-causing agents from cooking work in the body offers believable reasons for these connections. Red meat contains important nutrients, but evidence suggests people should eat it in moderation [21]. Cutting back on processed meat can reduce cancer risks. Fruits and vegetables rich in vitamin C also contain a variety of other beneficial phytochemicals, antioxidants, and fiber that may synergistically contribute to cancer prevention. The use of combined vitamin A, C, and E supplements showed an association with a decreased risk of colon polyps; vitamin C protects against the risk of colorectal cancer. Future studies need to explore how cancers form, examine the role genes play, and study how specific nutrients might protect us when thinking about our overall diet. These discoveries are crucial to provide health advice aimed at lowering cancer risk by adjusting our eating habits.

VI. CONCLUSION

The evidence from this review suggests that high consumption of red meat that is above 350-500g per week and especially with processed meat is associated with an increased risk of several cancers, particularly colorectal cancer [15]. These findings reinforce current dietary recommendations to limit red meat intake as part of a healthy diet.

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