

JĪRṆA ĀHĀRA LAKṢAṆA AS A PUTATIVE PHYSIOLOGICAL TIMER OF KṢUT: AN AYURVEDIC-ENDOCRINE- CHRONOBIOLOGICAL FRAMEWORK FOR FUTURE FUNCTIONAL FOOD RESEARCH

Dr. Varshanath B.^{1*}, Dr. Harikrishnan G.²

^{1*} Assistant Professor, Department of Swasthavritta, SCPM Ayurvedic Medical College,
Lucknow Road, Haripur, Gonda, Uttar Pradesh – 271003, India.

² Assistant Professor, Department of Rasashastra Evam Bhaishajya Kalpana, SCPM
Ayurvedic Medical College, Lucknow Road, Haripur, Gonda, Uttar Pradesh – 271003, India.

Article Received on 15 Sept. 2026,
Article Revised on 05 October 2026,
Article Published on 16 October 2026,

<https://doi.org/10.5281/zenodo.234327>

***Corresponding Author**

Dr. Varshanath B.

Assistant Professor, Department of
Swasthavritta, SCPM Ayurvedic
Medical College, Lucknow Road,
Haripur, Gonda, Uttar Pradesh –
271003, India.



How to cite this Article: Dr. Varshanath B.^{1*},
Dr. Harikrishnan G.². (2026). Jīrṇa Āhāra
Lakṣaṇa As A Putative Physiological Timer Of
Kṣut: An Ayurvedic-Endocrine-
Chronobiological Framework For Future
Functional Food Research. World Journal of
Pharmaceutical Research, 15(20), 1451–1471.

This work is licensed under Creative Commons
Attribution 4.0 International license.

ABSTRACT

Ayurveda considers digestion not as a process that only begins and ends with the food being consumed, but one that is complete when specific bodily signals are observed, collectively referred to as Jīrṇa Āhāra Lakṣaṇa. Of special interest is Kṣut which can be translated as ‘natural emergence of hunger’, as it is this sign that signals the organism’s readiness to receive nourishment. Other signs include Udgāraśuddhi, Lāghava, Utsāha, Viṣṭabdhā/normal bowel movement and Pipāsā, with variations reported in different Ayurvedic traditions. Modern physiologists recognize that appetite is controlled by neuroendocrine circuits connecting the gut, hypothalamus and reward centres, with ghrelin, leptin, GLP-1, PYY, CCK, insulin, nutrient sensing and circadian clocks contributing to the control of feeding. Ghrelin decreases after eating and increases before meals. Leptin plays a role in long-term energy regulation and displays diurnal variation.

Thus, it is tempting to hypothesize that the Ayurvedic sequence of physiological signs announcing the end of digestion and the natural emergence of hunger might encode an ancestral physiological clock. This review suggests that Jīrṇa Āhāra Lakṣaṇa might provide

an Ayurvedic functional phenotype for the development of chrono-functional foods, to maintain or enhance the body's natural temporal organisation of hunger and satiety.

KEYWORDS: *Jīrṇa Āhāra Lakṣaṇa*, *Kṣut*, Ayurveda, ghrelin, leptin, chrononutrition.

INTRODUCTION

Nutrition has traditionally focused on the qualitative and quantitative aspects of food, including what should be consumed, in what quantity, and with what nutritional composition. Contemporary research has expanded this perspective through the emergence of chrono nutrition, which emphasizes the importance of *when* food is consumed in relation to circadian rhythms, metabolic processes, sleep–wake cycles, and hormonal regulation. However, an equally fundamental question is how the body determines that it is physiologically ready to receive another meal.

Ayurveda provides an intriguing conceptual framework for this question through the description of *Jīrṇa Āhāra Lakṣaṇa*, the signs associated with completion of digestion. Classical Ayurvedic literature describes several features indicating that the previously consumed food has undergone digestion and that the body is prepared for subsequent food intake. Among these, *Kṣut* (natural hunger) occupies particular importance. Other associated features described in different classical sources include clarity of belching (*Udgāraśuddhi*), lightness of the body (*Lāghava*), appropriate thirst (*Pipāsā*), enthusiasm or functional readiness (*Utsāha*), and normal elimination (*Vegotsarga*). Although descriptions vary among texts and traditions, the underlying concept is that the emergence of physiological signs after digestion provides an indication of readiness for the next meal.

Modern appetite physiology similarly recognizes that hunger is not merely a psychological response but arises from complex interactions among gastrointestinal, endocrine, neural, metabolic, and circadian systems. The gut–brain axis integrates information regarding gastric distension, nutrient availability, glucose and lipid metabolism, and circulating hormones. Among the appetite-regulating hormones, ghrelin has attracted particular attention because its concentrations generally increase during fasting and before meals and decrease following food intake. Leptin, insulin, glucagon-like peptide-1 (GLP-1), peptide YY (PYY), cholecystokinin (CCK), glucose, free fatty acids, and vagal and hypothalamic pathways also contribute to the regulation of hunger and satiety.

These observations raise an intriguing question: could the Ayurvedic description of *Kṣut* following *Jīrṇa Āhāra Lakṣaṇa* represent, at least conceptually, an integrated physiological transition from a postprandial state toward readiness for subsequent food intake? Such a proposition should not be interpreted as evidence that an Ayurvedic concept is identical to a specific modern hormone or pathway. Rather, it provides a hypothesis that can be investigated using contemporary physiological and chronobiological methods.

The present review therefore examines the relationship between *Jīrṇa Āhāra Lakṣaṇa*, *Kṣut*, appetite regulation, ghrelin and other metabolic signals, with particular emphasis on the emerging field of chrononutrition. It proposes the *Jīrṇa–Kṣut axis* as a conceptual framework describing the possible transition from completion of the previous digestive cycle to physiological hunger and subsequent meal initiation. The review also explores the potential implications of this framework for meal timing, metabolic health, precision nutrition, and the future development of chrono-functional foods.

MATERIALS AND METHODS

The present work was designed as a narrative and conceptual review integrating classical Ayurvedic descriptions with contemporary evidence from appetite physiology, endocrinology, gastroenterology, chronobiology, and nutrition science.

Literature Sources

Relevant classical Ayurvedic literature concerning *Āhāra*, *Jīrṇa Āhāra*, *Jīrṇa Āhāra Lakṣaṇa*, *Kṣut*, *Agni*, and appropriate timing of food intake was considered for the Ayurvedic component of the review. Classical descriptions were examined to identify recurring signs associated with completion of digestion and readiness for subsequent food intake.

For the modern component, scientific literature concerning hunger, satiety, ghrelin, leptin, GLP-1, PYY, CCK, insulin, glucose, free fatty acids, gastric distension, vagal signalling, hypothalamic appetite pathways, circadian rhythms, meal timing, and chrononutrition was considered.

Conceptual Integration

The Ayurvedic and contemporary physiological concepts were examined independently before attempting conceptual integration. The analysis focused on identifying functional

parallels rather than assuming direct equivalence between traditional Ayurvedic terminology and modern biological entities.

Particular attention was given to the following conceptual sequence:

Āhāra → digestion → *Jīrṇa Āhāra Lakṣaṇa* → *Kṣut* → subsequent Āhāra

This was compared conceptually with the modern sequence:

Food intake → gastrointestinal processing → nutrient sensing → postprandial satiety → declining satiety signals → orexigenic signalling → subjective hunger → meal initiation.

Analysis of Appetite and Chronobiological Mechanisms

The role of ghrelin was examined in relation to fasting, meal initiation, postprandial suppression, and circadian variation. Other appetite-regulatory mechanisms, including leptin, GLP-1, PYY, CCK, insulin, glucose, free fatty acids, gastric distension, vagal signalling, and hypothalamic pathways, were considered to avoid reduction of hunger physiology to a single hormonal mechanism.

The bidirectional relationship between circadian clocks and feeding behaviour was also examined, particularly the influence of meal timing on metabolic hormones and appetite rhythms.

Hypothesis Development

Based on the synthesis of the available concepts, the following hypotheses were developed:

- *Kṣut* may represent an integrated physiological state of readiness for subsequent food intake rather than an isolated sensation.
- The transition from *Jīrṇa Āhāra Lakṣaṇa* to *Kṣut* may have measurable endocrine, metabolic, and neural correlates.
- Ghrelin may contribute to this transition but is unlikely to represent its sole biological mediator.
- Meal timing and circadian organization may influence the temporal relationship between digestive completion and hunger emergence.
- The proposed *Jīrṇa–Kṣut* axis may provide a testable conceptual framework for future chrono nutrition research.

The proposed mechanisms are presented as hypotheses rather than established causal relationships.

RESULTS AND DISCUSSION

From “When to Eat” To “When the Body is Ready to Eat”

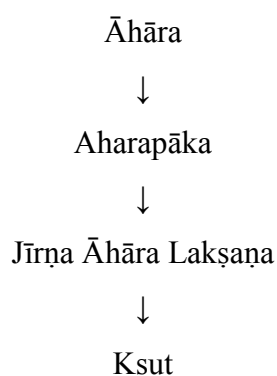
Modern nutrition talks about what we should and shouldn't eat. The new discipline of chrono nutrition asks also when we should and shouldn't eat. An even more foundational question may be how the body knows when it is ready to eat. This question links Ayurveda with modern appetite physiology. Ayurveda talks about the natural emergence of hunger as part of Jīrṇa Āhāra Lakṣaṇa. A review of classical descriptions finds Kṣut, or hunger, and other signs as part of the indicators that digestion is complete and another meal can be received. Meanwhile, modern physiology increasingly appreciates that the sensation of hunger is not merely psychological, but rather is controlled by neuroendocrine circuits connecting the gut with the brain. These circuits also control satiety. Ghrelin, the hunger hormone, decreases after eating and increases before meals. This raises the possibility that the Ayurvedic description encodes a deeper endocrine truth. This review therefore explores the intriguing possibility that Kṣut, the natural emergence of hunger described after Jīrṇa Āhāra Lakṣaṇa, encodes a broader neuroendocrine transition.

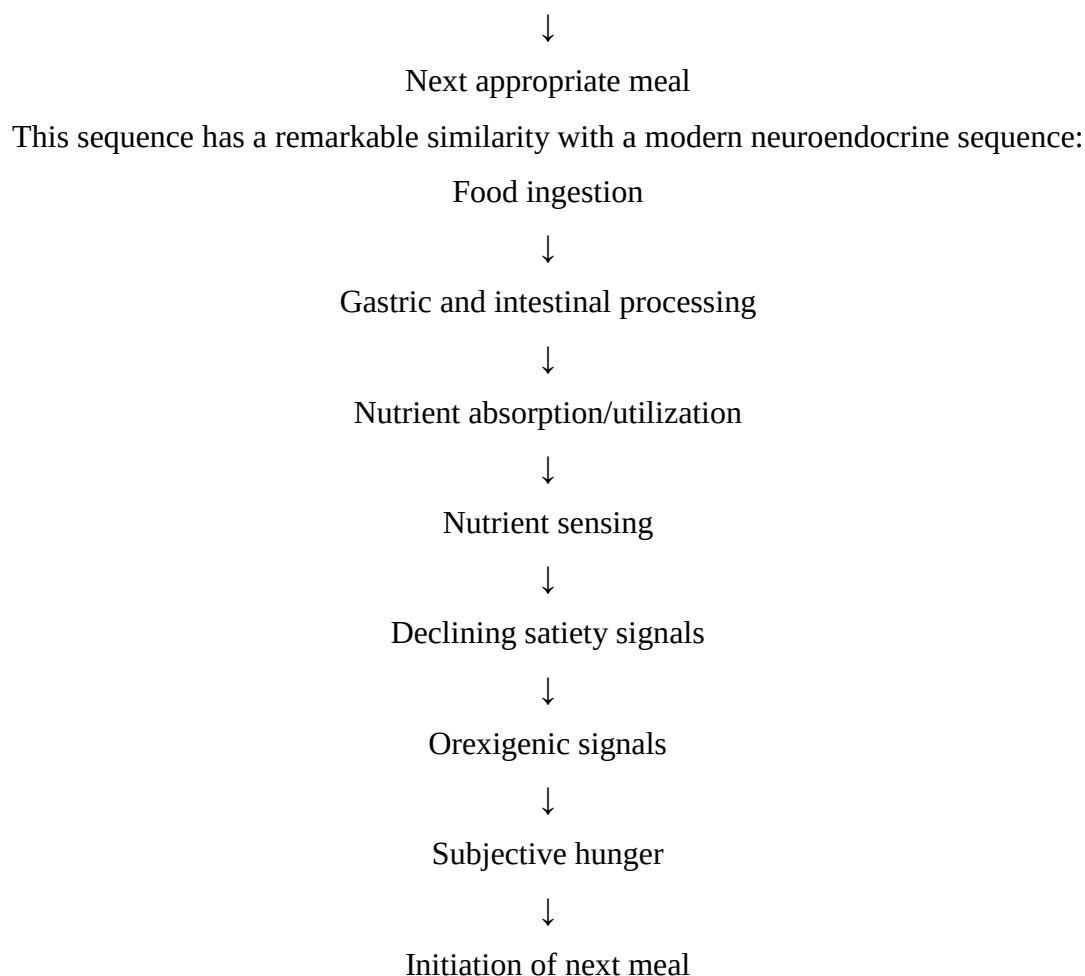
Jīrṇa Āhāra Lakṣaṇa: The Ayurvedic “Post-Digestive State”

The Ayurvedic construct should first be reviewed on its own terms. Jīrṇa Āhāra refers to food that has been digested. Specific signs therefore indicate that the meal has been digested and that the body is ready for another meal. The signs include Udgāraśuddhi or clear belching, Lāghava or lightness, Pipāsā or thirst, Utsāha or enthusiasm, appropriate elimination of waste products (Vegotsarga) and normal bowel movements (Viṣṭabdha), and so on, with variations reported across different Ayurvedic traditions. Kṣut is therefore not an isolated phenomenon, but is part of a sequence of post-digestive states that are important for the next meal.

From Digestion to Eating Again

The conceptual sequence can be presented as follows:





The parallel between the two sequences is noteworthy, though obviously the specific details differ.

Ghrelin: The Most Important Molecular Link

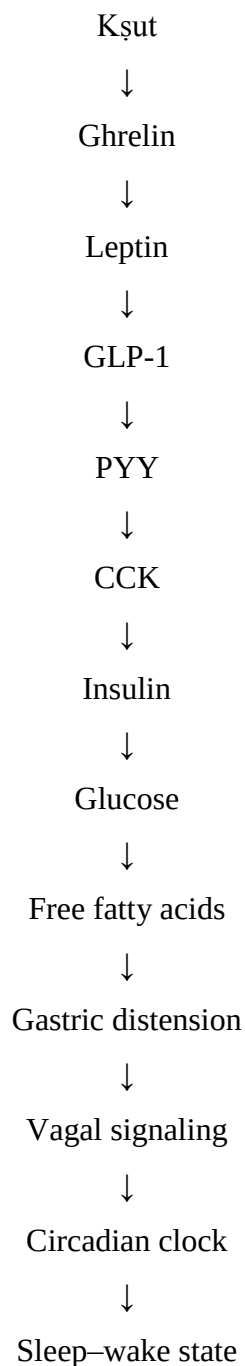
Among the neuroendocrine links, it is useful to single out ghrelin which controls appetitive hunger. Ghrelin has been found to rise before meals and fall after eating, while also displaying circadian variations. In humans, fasting leads to ghrelin increases which in turn lead to subjective hunger and food intake, which causes ghrelin suppression. It has been noted also that ghrelin is under the control of circadian clocks. This means that the hormone displays predictable variations throughout the day and prepares the body for feeding at specific times.

Beyond Ghrelin: Why the “Ghrelin–Leptin Cascade” Is Too Simple

A futuristic review should not be overly committed to any one hormone. Thus, the view that ghrelin is the proximate controller of appetite is complicated by the presence of other hormones. Leptin plays a role in long-term energy regulation and displays circadian variation

in secretion. More specifically, ghrelin and leptin do not act in a simple “ghrelin cascade” and “leptin cascade”. A review of human appetite physiology specifically notes that ghrelin does not appear to be a direct regulator of leptin; rather, these hormones converge on the hypothalamus to regulate satiety.

Thus, the complete picture probably involves:



Leptin: The Longer-Term Energy Signal

Leptin provides a useful counterpart to ghrelin.

While ghrelin has prominent roles in short-term regulation of hunger, leptin is more involved in long-term energy regulation.

It comes from adipose tissue which informs the body about its energy status.

It also displays circadian variations.

Together, these hormones contribute to the regulation of appetite and satiety.

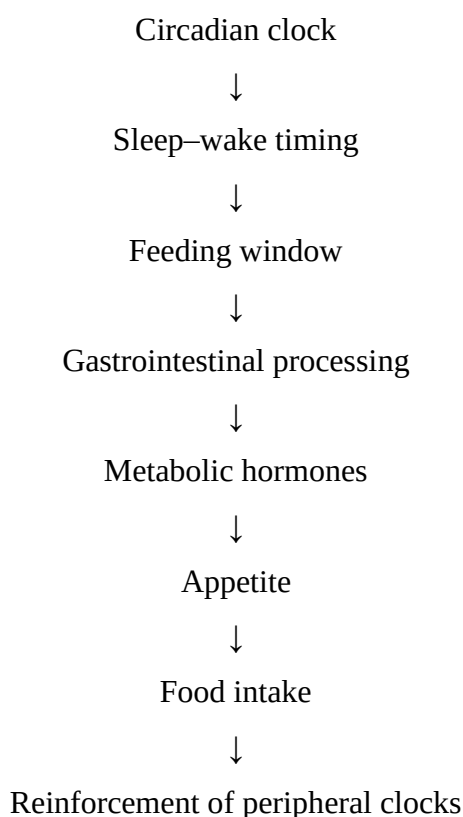
7. Chronobiological Considerations

The most visionary element of this discussion is probably the role of time.

It has been appreciated that the circadian clock regulates feeding and metabolism, while feeding also regulates the circadian clock.

The relationship is complex and bi-directional.

Briefly:



It is also noteworthy that meal timing influences ghrelin dynamics.

Chrononutrition researchers are currently investigating how ghrelin rhythms can be manipulated for health. It may be informative to hypothesize also that these regulators contribute to encoding Jīrṇa Āhāra Lakṣaṇa.

8. Kṣut: A “Physiological Readiness-to-Eat Phenotype” Concept

Based on this discussion, it may be tempting to propose a new concept:

Kṣut may be considered as a physiological readiness-to-eat phenotype.

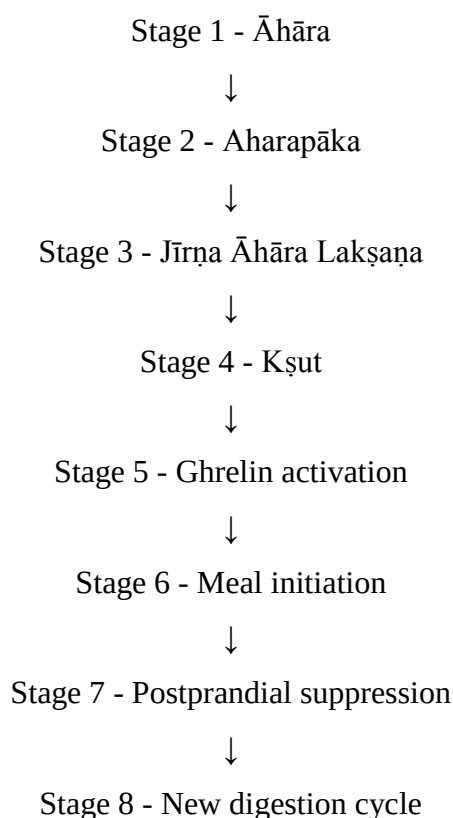
This means that Kṣut embodies a readiness-to-eat state which is encoded in an endocrine transition from the post-digestive satiety state to the pre-feast orexigenic state.

Thus, Kṣut embodies a wider physiological transition than ghrelin alone.

9. The Proposed Jīrṇa–Kṣut–Ghrelin Axis

Based on this discussion, it may be possible to propose a new conceptual model.

The Jīrṇa-Kṣut-Ghrelin Axis is presented below:



This model should be presented more as a hypothesis which requires further investigation than a proven fact.

10. The Concept of Ghrelin “Pulsatility”: Why “High” or “Low” Is Not Always Important

A future direction in this research might be to move from asking “what is ghrelin” to asking “is ghrelin occurring at the appropriate time?”

This is a truly visionary approach.

Hormones such as ghrelin probably need to exhibit appropriate pulsatility for health.

Thus, asking about “appropriate ghrelin” probably makes more sense than asking about “high ghrelin” or “low ghrelin”.

A recent review emphasizes meal timing as a key determinant of ghrelin dynamics.

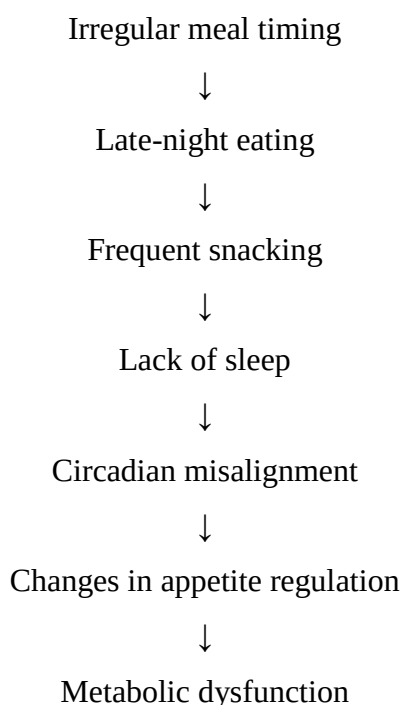
Applying this principle to the Ayurvedic concept, it may be possible to suggest that ghrelin is central to Kṣut, but that it is not the sole contributor and that other hormones and satiety factors should be considered.

11. What Happens When the System Malfunctions?

There is no single cause for malfunction.

It may be informative to contrast the Ayurvedic model with the modern obesogenic environment.

The latter can be summarized as follows:



A brief review of the literature will indicate that the dysregulation of circadian organisation and mistimed eating contribute to metabolic dysfunction.

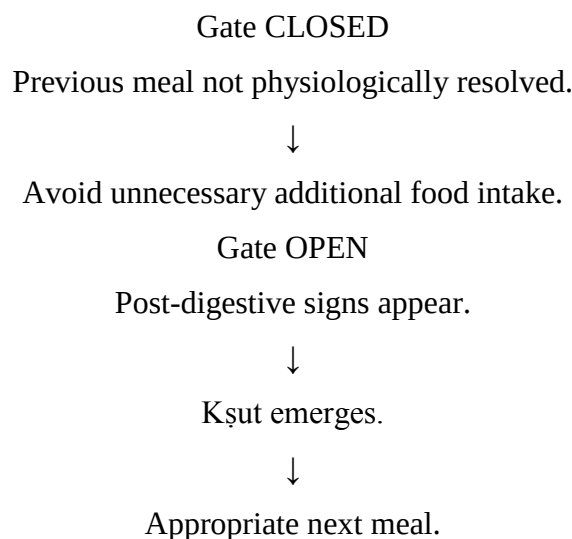
This can be contrasted with the Ayurvedic wisdom which talks of Jīrṇa → Kṣut → Āhāra and implies that eating should be determined by the digestion state.

Thus, while the modern environment talks about exogenous determinants of eating (clocks), Ayurveda talks about endogenous determinants.

12. Jīrṇa Āhāra Lakṣaṇa as a Biological “Gate”

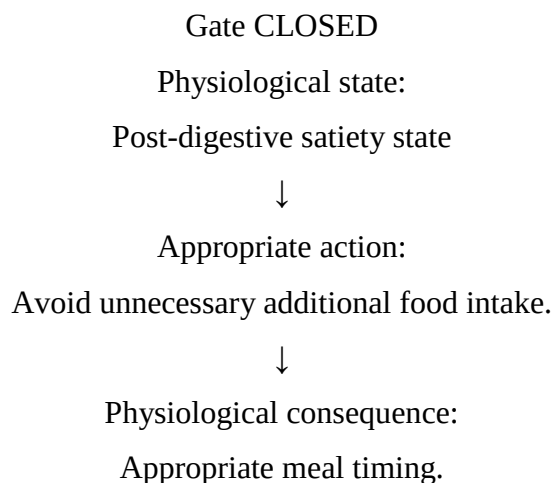
The discussion leads to an even more interesting proposition.

Perhaps Jīrṇa Āhāra Lakṣaṇa can be conceptualized as a biological gate:



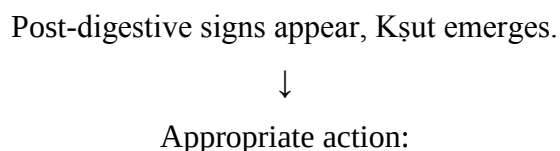
This concept can be expanded as follows:

Physiological gate



Gate OPEN

Physiological state:



Physiologically appropriate food intake.

Thus, this concept can be applied to the modern understanding of grazing, snacking, emotional eating, late-night eating, obesity and related conditions.

13. From “Functional Food” to “Chrono-Functional Food”

This perspective leads to the concept of a chrono-functional food.

Most functional foods are currently evaluated according to their nutritional and biochemical properties.

The next generation can go beyond this and add a chrono-biological dimension.

Chrono-functional foods would have physiological benefits beyond basic nutrition.

It would be possible to design a chrono-functional food based on the proposed Ayurvedic gate mechanism.

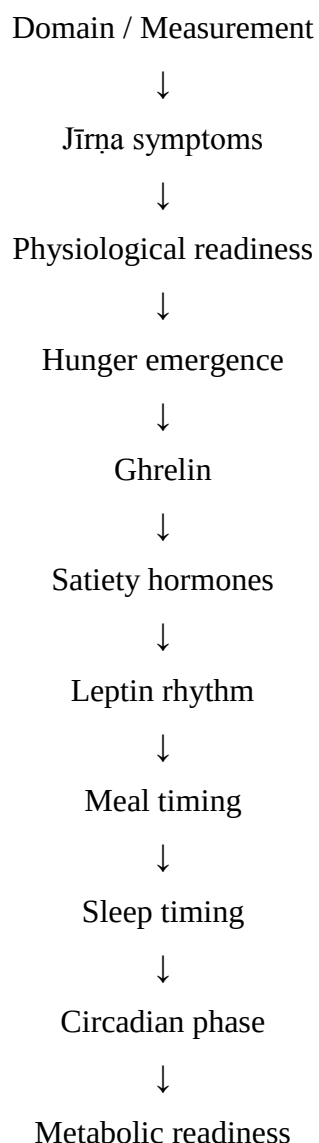
A chrono-functional food would be evaluated according to the following criteria:

Food composition
+
Digestibility
+
Meal timing
+
Glycaemic response
+
Ghrelin response
+
Satiety hormone response
+
Circadian phase
+
Time to subsequent physiological hunger.

14. The PROTECTED FOREIGN QUOTE - 1

A quantitative assessment would be useful at this point.

It may be possible to design a Kṣat Synchronization Index as follows:

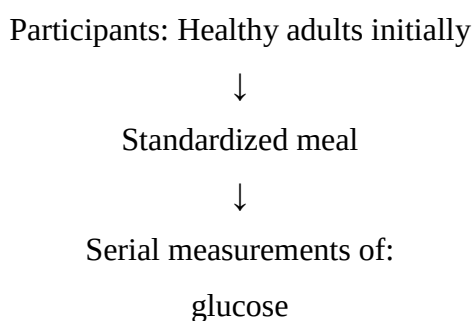


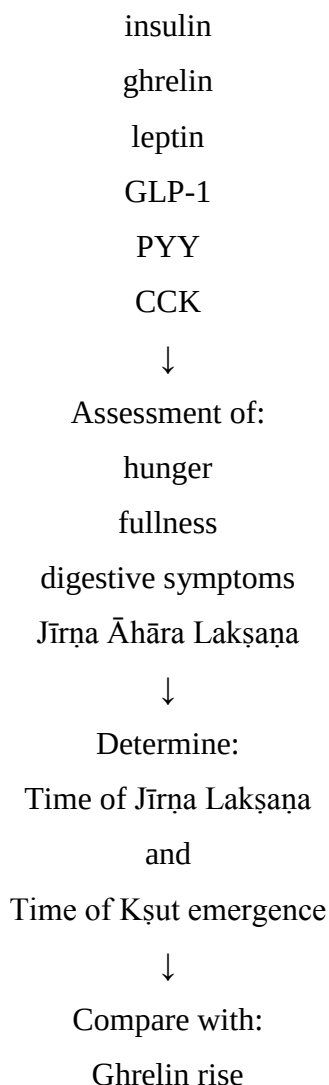
The index would then indicate how well subjective Kṣut corresponds to physiological readiness for the next meal, thus incorporating Ayurvedic wisdom into a modern framework.

15. A Future Experimental Model

Future researchers can apply the hypothesis in a clinical study.

The design can be as follows:





Test the association of Jirṇa Lakṣaṇa with the endocrine transition from satiety to hunger.

It is especially important to test the following question: Does Kṣut emergence temporally coincide with characteristic endocrine changes?

16. The Most Important Future Experiment

A truly visionary experiment would be to compare the following three groups/conditions:

Group A: Regular meal timing

Group B: Delayed meal timing

Group C: Irregular meal timing

Measure Jirṇa Lakṣaṇa → Kṣut → ghrelin → next meal

If the Ayurvedic hypothesis is correct, regular eating should lead to better synchronisation between digestion completion and hunger onset.

In other words, regular eating will lead to a better temporal link between digestion and ghrelin rises.

17. Functional Foods: Designing to Support Rather Than Suppress Hunger

The ultimate application of this knowledge might be to develop a new type of a functional food.

Instead of suppressing hunger, such a food could be designed to support the body's own hunger–satiety system.

This would be the essence of a chrono-functional food described above.

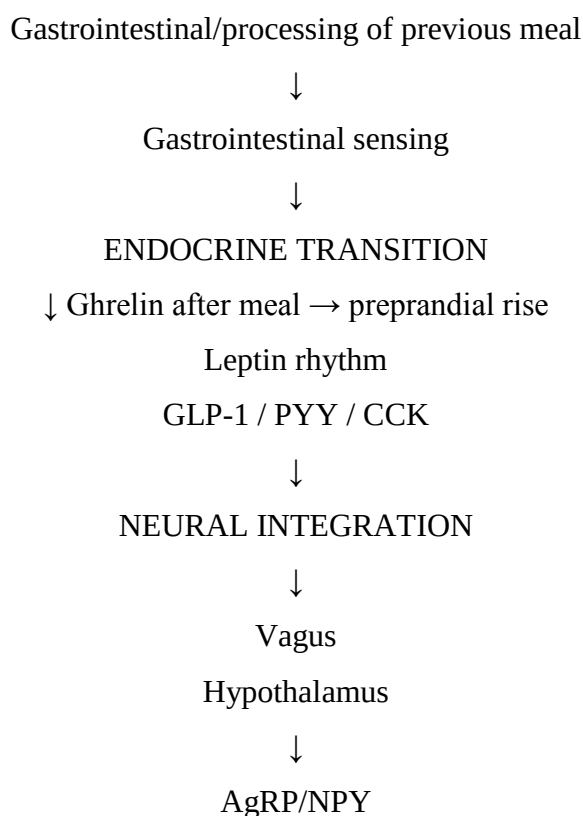
Such a food should have the following characteristics:

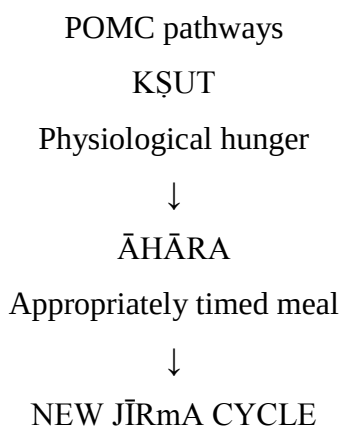
- Adequate satiety after eating, without excessive postprandial glycaemic excursions
- Allow physiological emergence of hunger
- Avoid prolonged suppression of hunger
- Maintain meal-to-meal hormonal responses

This is a truly visionary concept.

18. Proposed Mechanistic Framework

JIRmA





19. A New Concept: “Metabolic Conversation”

One of the most valuable contributions of this review might be to present digestion and appetite as a conversation:

The previous meal communicates with the body to indicate when it is time for the next meal.

Jīrṇa Āhāra Lakṣaṇa embodies the Ayurvedic wisdom about this communication.

Ghrelin, leptin and other gut peptides are some of the messengers.

Kṣut indicates that the communication has occurred successfully.

Thus,

Food → digestion → sensing → endocrine → neural → hunger → food

is not a set of unrelated events, but rather a conversation?

20. From Ayurveda to Precision Nutrition

The future of precision nutrition may move from clocks to conversations.

Thus,

Clock-based nutrition

“Eat at 8 AM, 1 PM and 8 PM.”

vs.

Physiology-based chrononutrition

“Eat when your body indicates, within a broad temporal window.”

21. Proposed New Terminology

For this article, it may be appropriate to introduce three key concepts:

1. Jīrṇa-Kṣut Axis – the proposed relationship between the end of the previous digestive cycle and the beginning of physiological hunger.

2. Kṣut synchronization – the temporal concordance between subjective and physiological aspects of hunger.
3. Chrono-functional food – a functional food with chrono-biological properties that go beyond conventional nutritional and biochemical evaluation.

22. What the review can legitimately claim now

Established

- Ghrelin participates in hunger and meal initiation.
- Ghrelin rises during fasting and generally decreases after food intake.
- Appetite-regulatory hormones have temporal/circadian organization.
- Meal timing can influence appetite and metabolic physiology.
- Regular meal timing can influence ghrelin dynamics.
- Circadian disruption and mistimed eating are associated with metabolic consequences.
- Ayurveda describes Kṣut among the signs associated with completion of digestion.

Proposed

- Kṣut may be an integrated physiological phenotype.
- Jīrṇa Āhāra Lakṣaṇa may identify the transition toward physiological meal readiness.
- The Jīrṇa-Kṣut relationship may have measurable endocrine correlates.
- Ghrelin may be one - but not the only - molecular mediator.
- Functional foods could potentially be designed to preserve this temporal relationship.

Not yet established

- That Jīrṇa Āhāra Lakṣaṇa directly causes ghrelin secretion.
- That Kṣut is equivalent to a ghrelin surge.
- That Ayurveda's Agni is identical to any single modern metabolic pathway.
- That leptin is simply the immediate post-digestive counterpart of ghrelin.

Maintaining this distinction will make the review more credible to a scientific reviewer.

23. The futuristic hypothesis

The entire review can ultimately converge on this hypothesis:

“Jīrṇa Āhāra Lakṣaṇa may represent an observable Ayurvedic phenotype of the postprandial-to-preprandial physiological transition, in which completion of digestion is followed by re-emergence of Kṣut through coordinated gastrointestinal, metabolic, endocrine and circadian signalling. Ghrelin may constitute an important molecular mediator of this transition, while

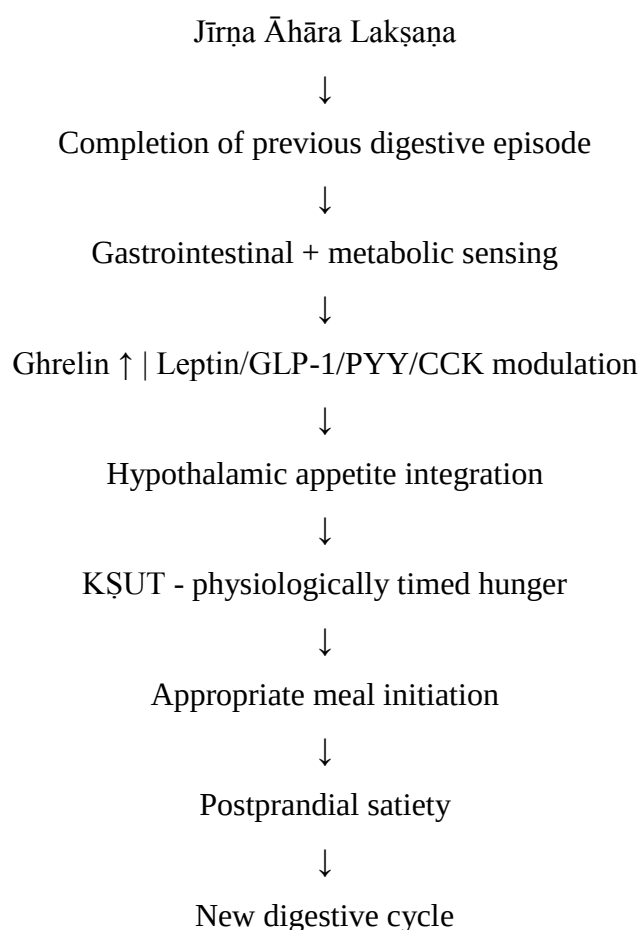
leptin and other satiety-related hormones provide complementary information about energy status and temporal appetite regulation.”

And the larger proposition is:

“Ayurvedic regulation of food intake may therefore be interpreted not simply as regulation of food quantity, but as preservation of the temporal architecture of hunger and satiety.”

That is, in my view, the strongest futuristic thesis for the article.

Proposed graphical abstract



Surrounding the entire cycle:

Circadian clock + sleep–wake rhythm + meal timing

And at the translational end:

Chrono-Functional Food → Preservation of Hunger–Satiety Rhythmicity → Metabolic Health.

CONCLUSION

The Ayurvedic description of *Jīrṇa Āhāra Lakṣaṇa* provides an interesting conceptual framework for understanding the transition from completion of one meal to readiness for the next. Within this framework, *Kṣut* is not merely an isolated sensation of hunger but forms part of a broader post-digestive state associated with physiological readiness for subsequent food intake.

Modern appetite physiology demonstrates that hunger and satiety arise from complex interactions among gastrointestinal signals, metabolic substrates, endocrine hormones, neural pathways and circadian mechanisms. Ghrelin is an important component of this system, particularly because of its relationship with fasting and meal initiation, but it should not be considered the sole biological determinant of *Kṣut*.

The proposed *Jīrṇa–Kṣut axis* therefore represents a hypothesis in which the completion of the previous digestive cycle is followed by an integrated endocrine, metabolic and neural transition culminating in physiological hunger and appropriately timed food intake. The concept of *Kṣut* as a “physiological readiness-to-eat phenotype” may provide a useful framework for investigating the relationship between subjective hunger and objective metabolic readiness.

Importantly, the present review does not claim that *Jīrṇa Āhāra Lakṣaṇa* is equivalent to a specific modern endocrine process, that *Kṣut* is synonymous with a ghrelin surge, or that *Agni* can be reduced to a single modern metabolic pathway. Instead, it proposes experimentally testable relationships between classical Ayurvedic observations and contemporary physiology.

Future research combining Ayurvedic assessment with serial measurements of ghrelin, leptin, GLP-1, PYY, CCK, glucose, insulin, circadian phase and subjective hunger may determine whether the emergence of *Kṣut* corresponds to a reproducible physiological transition. Such interdisciplinary research could contribute to a more individualized model of chrono nutrition in which meal timing is informed not only by the clock but also by the physiological signals of the body.

Thus, the future of this field may lie not simply in asking “What should we eat?” or “When should we eat?”, but also in understanding “How does the body communicate that it is ready

to eat?” The Ayurvedic concept of *Jirṇa Āhāra Lakṣaṇa* and *Kṣut* offers a historically rooted hypothesis that may be explored through the tools of modern physiology, endocrinology and chronobiology.

FUTURE SCOPE OF THE STUDY

The proposed relationship between *Jirṇa Āhāra Lakṣaṇa*, *Kṣut*, appetite-regulatory hormones and circadian physiology opens several important avenues for future interdisciplinary research. At present, the proposed *Jirṇa–Kṣut axis* should be regarded as a hypothesis-generating framework rather than an established physiological pathway.

REFERENCES

- 1) Khaira F, Sulastris D. Meal timing and ghrelin: A chrononutritional perspective on weight regulation potential. *Chronobiology International*, 2026; 43(5): 606-613. doi: 10.1080/07420528.2026.2624753. [PubMed](#)
- 2) Alotaibi A. Chrononutrition and cardiometabolic health: circadian timing as a dimension of precision nutrition. *Frontiers in Nutrition*, 2026. doi: 10.3389/fnut.2026.1779033. [PubMed](#)
- 3) Salas-González MD, Jiménez-Ortega AI, Loria-Kohen V, Lozano-Estevan MC. Chrononutrition and metabolic health: impact of meal timing on obesity and metabolic risk. *Nutrición Hospitalaria*, 2026; 43(Special No. 4): 63-66. doi: 10.20960/nh.06968. [PubMed](#)
- 4) Advancing Chrononutrition for Cardiometabolic Health: A 2023 National Heart, Lung, and Blood Institute Workshop Report. [Journal publication indexed in PubMed]., 2025. [PubMed](#)
- 5) Petrudi F, et al. Effects of early and late time-restricted feeding on parameters of metabolic health: an explorative literature assessment. *Nutrients*, 2024; 16(11): 1721. doi: 10.3390/nu16111721. [PubMed](#)
- 6) Carbone S, Pozzilli P. Chrononutrition in cardiometabolic diseases: current evidence and future perspectives. *Diabetes/Metabolism Research and Reviews*, 2024; 40. [PubMed](#)
- 7) Ruddick-Collins LC, Johnston JD, Morgan PJ, Johnstone AM. Meal timing, aging, and metabolic health. *International Journal of Molecular Sciences*, 2019; 20(8): 1911. doi: 10.3390/ijms20081911. [PubMed](#)
- 8) Kanoski SE, Grill HJ. Hippocampus contributions to food intake control: mnemonic, neuroanatomical, and endocrine mechanisms. *Biological Psychiatry*, 2017.

- 9) *The impact of gut hormones on the neural circuit of appetite and satiety: a systematic review.* 2017. This systematic review examined ghrelin, GLP-1, PYY, CCK, leptin, glucose and insulin within the gut–brain appetite network. [PubMed](#)
- 10) *Satiety: a gut-brain relationship.* *Journal of Physiological Sciences*, 2024. doi: 10.1186/s12576-024-00904-9. [PubMed](#)
- 11) *Appetite-related gut hormone responses to feeding across the life course.* 2025. This review discusses ghrelin, GLP-1, PYY and CCK and their relationships with appetite, feeding and body weight. [PubMed](#)
- 12) *Chrononutrition in the prevention and management of metabolic disorders: a literature review.* *Nutrients*, 2024; 16(5): 722. doi: 10.3390/nu16050722. [PubMed](#)
- 13) *Effects of timing of meal intake on glucose metabolism: a systematic review and meta-analysis of human intervention studies.* 2026. This recent meta-analysis found evidence that earlier meal timing can improve some short-term postprandial glycaemic outcomes, while emphasizing heterogeneity and the need for larger, longer trials.