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EFFECT OF PROCESSING PARAMETERS ON OIL UPTAKE OF INSTANT FRIED NOODLES

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Keywords

Abstract

The oil content is an important quality aspect of instant noodles being related to consumer acceptability and health implications. The present research work was intended to study the effect of varying processing variables on the oil uptake by the instant noodles. The processing variables included mixing time, resting time, number of folds, dough sheet thickness, steaming time, frying temperature and frying time. All these parameters exerted significant influence on the oil absorption by the noodles. Mixing time varied from 4 to 8 minutes with an oil uptake ranging from 18.84 to 25.37 minutes, respectively. Noodles made from unrested dough indicated higher oil uptake of 26.53% whereas those made from sufficiently rested dough (30 and 60 minutes) had comparatively lower oil absorption (18.84% and 17.46%, respectively). Incorporating a greater number of folds and reduced dough sheet thickness while making noodles restricted the oil uptake in the noodles. Steaming time showed a dramatic trend. Initially with an increase in steaming time from 5 to 7 minutes, the oil uptake decreased from 18.84 to 17.2%, however further steaming escalated the oil absorption. Frying parameters, time and temperature exhibited a direct relationship with the oil uptake. Frying at 140 oC for 90 seconds contributed to least oil uptake whilst frying at higher

Rajesh Kumar, Bhupendar Singh Khatkar (2025). *Effect of Processing Parameters on Oil Uptake of Instant Fried Noodles*. International Journal of Multidisciplinary Research & Reviews 4(4), 245-259.

	temperatures for prolonged period resulted in higher oil uptake. Conclusively, these findings provided an insight in optimizing the processing parameters to produce customer friendly low-calorie wholesome noodles without compromising their textural sand cooking quality attributes.

1. INTRODUCTION

Instant fried noodles have become one of the popular snacks across the globe. The processing of instant noodles involved several key stages including mixing of ingredients, resting, and sheeting, compounding, steaming and frying. Each of these stages contributed in a unique manner to provide desirable textural and eating quality attributes to the noodles. As the consumer preferences are highly dependent on the finished noodles characteristics, henceforth it is important to monitor these processes.

Several researchers have carried out work on the processing variables and studied their effects in relation to the oil uptake in instant noodles. Mixing is the preliminary stage wherein the wheat flour is combined with other ingredients such as salt or kansui, emulsifiers, hydrocolloids etc in the presence of water. The mechanical action imparted during mixing enabled the protein and starch fraction of flour to absorb water and form a continuous matrix of gluten (Cappelli, Bettaccini, & Cini, 2020). Zhu, He, Obadi, Qi, and Xu (2022) reported that mixing carried out under vacuum conditions is preferable owing to flour's enhanced ability to absorb water. The mixing parameters such as mixing speed and time, in association with dough temperature are important determinants for noodle quality (Shao, Guo, Li, & Zhu, 2019). The amount of water added during mixing stage for kneading the dough is again an important criterion. Overly moist dough tends to possess poor sheeting with higher chances of ripping, in contrast to dry dough which will undergo inadequate gelatinization during steaming. Followed by mixing is the resting stage which has a role to play in assisting the interaction among several flour's components, encouraging protein and starch to absorb more water, reorganizing the dough's internal structure, and facilitating the dough's uniformity and elasticity (Y. Li, Chen, Li, Gao, & Dong, 2017).

The resting conditions, particularly the temperature, relative humidity, and the duration affected the dough considerably and oil uptake in the product (Jiang, Yao, Sun, & Zhu, 2014). Optimally rested dough possessed smooth surface, desirable elasticity, compact and well-defined gluten network. On the contrary, poorly rested dough had loose and uneven gluten matrix which resulted in greasy and cracked noodles (S. Liu et al., 2021). Furthermore, Gulia, Dhaka, and Khatkar (2014) highlighted the importance of sheet thickness with respect to oil absorption by noodles. Thinner noodles exposed greater surface area during frying, which allowed more spaces for the oil to penetrate. Moreover, it has also been observed that passing the dough sheet through rollers several times appeared to be related to higher fat uptake. Therefore, to limit the oil uptake, it is preferred to combine extruder with single rolling-press to achieve a porous mesh structure, with the gluten network scattered freely within this (Tanaka et al., 2017). Steaming is important with respect to several changes in the dough structure caused by starch gelatinization, conversion of

Rajesh Kumar, Bhupendar Singh Khatkar (2025). *Effect of Processing Parameters on Oil Uptake of Instant Fried Noodles.* International Journal of Multidisciplinary Research & Reviews 4(4), 245-259.

starch granules from crystalline state to amorphous state and protein denaturation (Dhital, Katawal, & Shrestha, 2010). Under-steaming may cause the noodles to be fragile and taste starchy post-cooking while over-steaming let the noodles lose their snackability (Adejuwon, Jideani, & Falade, 2020). Contradictory results have been reported on the steaming conditions employed and the oil uptake in noodles. Gulia and Khatkar (2013) concluded that there is a linear relationship between steaming time and fat absorption rate of fried instant noodles. However, Ding and Liu (2009) indicated that employing a steaming time of 3 minutes reduced the fat uptake by 21.5%.

Frying is the most critical process with respect to the oil uptake in instant noodles. The type of oil and the frying conditions employed had a considerable effect on the oil absorption characteristic of instant noodles. Sanibal and Mancini-Filho (2004) compared the effects of oil having unsaturated fatty acids with that having saturated fatty acids. The results conferred that oil with unsaturated fatty acids resulted in noodles with higher oil uptake and lesser stability. Contrarily, oils with saturated fatty acids contributed surpassing stability during frying. Unsaturated cotton seed oil is an exception to this, exhibiting contradictory behavior to oil absorption over the palm oil (Vitrac, Trystram, and Raoult-Wack 2000).

Besides this, highly viscous oils with lower surface tension resulted in strong adherence of oil to the product surface with lower uptake in the capillaries. The frying temperature and time are crucial factors for regulating the extent of oil uptake in instant noodles. There have been many researchers who studied the effects of these conditions on oil uptake. While frying Gethi strips, an increase in oil uptake was observed at higher frying temperatures than lower temperatures for the same duration indicating an intense mass transfer phenomenon occurring at higher temperatures (Manjunatha, Ravi, Negi, Raju, & Bawa, 2014). Similar results were reported by (Krokida, Oreopoulou, and Maroulis (2000); Pinthus and Saguy (1994)) in French fries and other deep fried foods.

2. MATERIALS AND METHODS

2.1 Materials

Refined wheat flour was procured from local market. Hydroxypropyl methylcellulose (HPMC),) and other chemicals used were of analytical grade.

2.2 Noodle making

The development of instant noodles was achieved through the implementation of improved processing conditions and formula, as demonstrated by Gulia and Khatkar in their study conducted in 2013. The dough was made through the amalgamation of flour and a water solution comprising dissolved salts, namely Kansui and sodium chloride, along with the addition of guar gum. This process was carried out for duration of four minutes using a mixer for mixing time variations. The dough that had been made was rolled out to a thickness of 3.2 mm and thereafter allowed to rest for duration of 10 minutes within a sealed pouch in order to minimize the loss of moisture. Subsequently, the dough sheet was adjusted to a thickness of 1.2 mm and allowed to rest for duration of 30 minutes within a zip lock pouch. The sheets were divided into strands and thereafter

Rajesh Kumar, Bhupendar Singh Khatkar (2025). *Effect of Processing Parameters on Oil Uptake of Instant Fried Noodles*. International Journal of Multidisciplinary Research & Reviews 4(4), 245-259.

positioned on a steamer tray, where they were subjected to a temperature of 100°C for duration of varying in minutes. The noodles underwent a process of deep frying in soybean oil at varying temperature for different durations, after which they were subsequently cooled for a period of 15 minutes. The samples of instant noodles were carefully cleaned to eliminate any surplus oil and thereafter placed in zip lock pouches for subsequent examination.

2.3 Fat analysis

The fat content of instant noodles was assessed using the automated Soxhlet extraction method, specifically employing the Soxtec™ 2050 Auto Fat Extraction System. The instant noodle samples, weighing 5 g each, were carefully placed into thimbles and afterwards introduced into the extraction device. A closed system was utilized to introduce a solvent, specifically petroleum ether 40/60 pa, into the extraction cups. The containers underwent thermal heating through the utilization of an electric heating panel. The extraction process involved four steps: boiling for duration of 25 minutes, rinsing for 35 minutes, recovering the solvent for 15 minutes, and pre-drying for 45 minutes. Three replicates were conducted for each measurement, and the mean values obtained were utilized for statistical analysis. The dried samples were precisely re-weighed, and the fat content was determined by employing the subsequent equation:

Fat Content (%) = (Initial weight of Sample-Final Weight of sample)/ (Initial weight of Sample) ×100

3. RESULTS AND DISCUSSION

Mixing, resting, sheeting, steaming and frying are the fundamental stages involved in the processing of instant noodles. A summary of the effects of these processing parameters on the oil uptake quality of instant noodles has been presented in Table 1.

Table 1: Summary of the effects of processing variables on the oil uptake of instant noodles

Parameter	Conditions employed	Oil uptake (%)
Mixing time (min)	**4**, 5, 6, 7, 8	**18.84**, 19.64, 22.12, 23.8, 25.37
Resting time (min)	0, 30, **60**	26.53, 18.84, **17.46**
Number of folds	1, 3, **5**	23.63, 18.84, **17.29**
Dough sheet thickness (mm)	**1**, 1.5, 2	**18.84**, 22.46, 27.64
Steaming time (min)	5, 6, **7**, 8	18.84, 17.85, **17.2**, 18.8
Frying time (sec)	**90**, 120, 180	**18.03**, 18.84, 24.29
Frying temperature (°C)	**140**, 150, 170	**18.84**, 21.58, 23.84

- **Effect of mixing time on the Oil Uptake in Instant Noodles**

The instant noodle processing commenced with the dispersion of the dry ingredients, particularly wheat flour and salt (with or without the other optional ingredients) into the water to form homogenous mass called dough. While the dough is formed due to the mechanical action of the

Rajesh Kumar, Bhupendar Singh Khatkar (2025). *Effect of Processing Parameters on Oil Uptake of Instant Fried Noodles.* International Journal of Multidisciplinary Research & Reviews 4(4), 245-259.

mixer blades, flour's starch and protein fraction absorbed water and transformed into a three-dimensional network. This intertwined network is referred to as gluten wherein the proteins interacted with each other through the disulphide linkages and swollen starch granules serve as fillers (Cappelli et al., 2020). Mixing played a prominent role in building the structural integrity of the dough which governed the noodle quality. Mixing time, the total time required for the development of dough, is dependent upon several intrinsic and extrinsic factors. The hydration capacity of flour, dough temperature, and the mixing speed are some of the important factors influencing the mixing time.

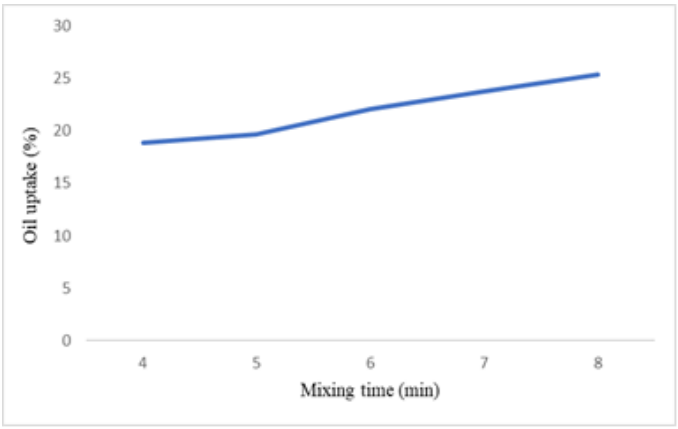

Fig 1: Effect of mixing time on oil uptake in instant noodles

The mixing time has been linked to the oil absorbed by the instant noodles as evident from Fig 1. As the mixing time increased from 4 to 8 minutes, there has been a gradual increase in the absorption of oil ranging from 18.84 to 25.37%. It can be interpreted that shorter mixing times tend to limit the oil uptake by the noodles, preferably by forming uniform, cohesive and elastic dough with reduced number and size of pores. However, prolonged mixing or over-mixing may interrupt the well-defined gluten network and developed drier and crumblier dough. In addition, excessive heat may be generated, which caused the protein denaturation and weakened the dough structure. As a result, non-uniform and less cohesive dough with larger pores was developed which incorporated more oil into the noodle strands. These results were in agreement with (Gulia and Khatkar (2013); Obadi et al. (2022)). The microstructural study of an optimally mixed dough carried out by Zhao et al. (2017) revealed the presence of a compact, well-stretched and continuous gluten matrix embedded with starch granules in a discontinuous manner.Bae, Kim, Inglett, and Lee (2016) reported that while using whole grain wheat flour for making noodles, higher water absorption with reduced kneading time were essential for mixing dough to optimal levels. Due to the reduced porosity of dough, oil uptake was minimized by 30%. Furthermore, Kim et al. (2013) attempted to reduce the oil uptake in the noodles by supplementing flour with pre-harvest dropped apple powder and observed that a dense and extended structure devoid of voids was culminated which refrained the oil to penetrate into the noodles.

Rajesh Kumar, Bhupendar Singh Khatkar (2025). *Effect of Processing Parameters on Oil Uptake of Instant Fried Noodles.* International Journal of Multidisciplinary Research & Reviews 4(4), 245-259.

- **Effect of resting time on the Oil Uptake in Instant Noodles**

Dough resting often referred to as proofing, ageing or maturing, is important for improving the machinability or processability of the dough. It facilitated gluten development by advancing the starch gelatinization process and boosting the uniform hydration of flour's components. A matured dough resulted in noodles with a smooth surface and poor adhesiveness (Hatcher, 2001). The immature dough exhibited irregularities in gluten formation, as well as poor starch gelatinization which conferred higher losses during post-processing.

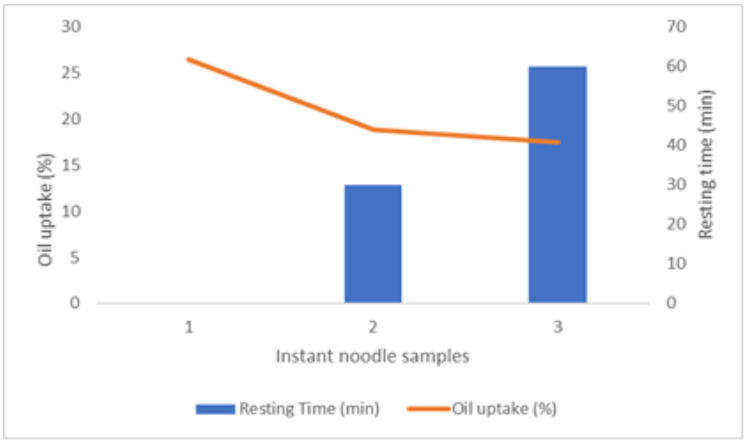

Fig 2: Effect of resting time on the oil absorption by instant noodles

An inverse relationship was observed between the resting period and the oil uptake by instant noodles (Fig 2). As indicated, with an increase in the resting period from 0 to 30 and 60 minutes, a decline in the oil absorption values i.e 26.53, 18.84, 17.46%, respectively was noticed. This drop in oil absorption was more significant from dough with no rest period to the one where sufficient time was given to the dough. Increasing the resting period beyond 30 minutes did not show a very significant depreciation in the oil uptake. This can be attributed to the fact that post mixing, coarse dough is formed with a slightly irregular gluten matrix. Allowing the dough to rest for some time ensured that the free water available in the dough was evenly distributed among starch and protein. Consequently, there was an escalation in the viscoelasticity of the dough and so the noodles, thereby reducing the oil uptake (Y. Li et al., 2017). Similarly, S. Liu et al. (2021) concluded that resting the dough for 30 minutes increased the content of glutenin macropolymer, which contributed to a uniform and compactly arranged gluten network. Moreover, this resting advanced gluten network in a transverse manner, on the contrary, resting for 60 and 90minutes improved gluten network in a longitudinal fashion. Overall, resting accomplished multitudinous functions: (1) ensured uniform distribution of moisture in the dough, (2) intensified interactions among proteins by encouraging disulfide linkages, (3) associating gluten and lipids and (4) relaxed the gluten network for subsequent sheeting operation (Hou, 2001). A temperature of about 25oC has been contemplated as an ideal temperature for dough resting. Higher temperatures intensified the protease activity in the flour, which hampered the quantity as well as quality of wet gluten (Jiang et

Rajesh Kumar, Bhupendar Singh Khatkar (2025). *Effect of Processing Parameters on Oil Uptake of Instant Fried Noodles*. International Journal of Multidisciplinary Research & Reviews 4(4), 245-259.

al., 2014). This impaired gluten failed to form a fine matrix and resulted in higher oil penetration in the noodles. It has also been postulated that properly rested dough produced noodles with improved textural and cooking quality when compared to noodles prepared from dough without resting (Obadi, Li, Qi, & Xu, 2023).

- **Influence of number of folds and dough sheet thickness on the oil penetration in noodles**

Sheeting is a process of passing the properly rested dough through a roller to achieve a compact and uniform dough sheet. As an effect of compressive forces being exerted onto the sheet during this process, a sudden transformation from a relatively disordered to a much-ordered, layered, and fibrous gluten structure occurred (Amend & Belitz, 1990) The extent of this change is dependent upon the number of folds and the dough sheet thickness.

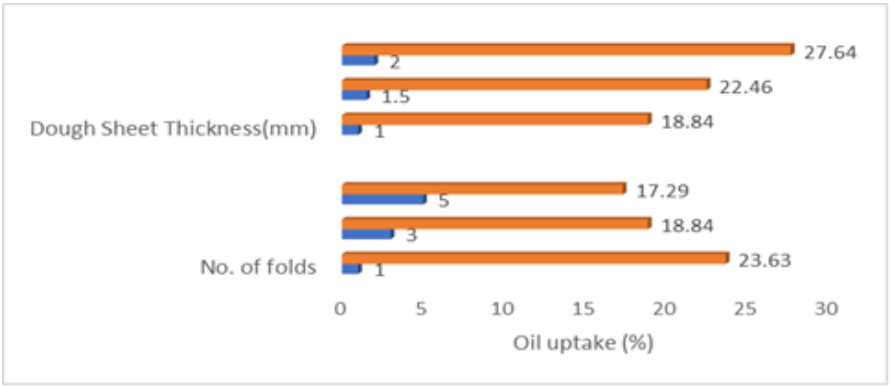

Fig 3: Number of folds and thickness of dough sheet vs. oil uptake

As depicted in Fig 3, there is an inverse relationship between the number of folds the sheet undergoes and the oil uptake by the resultant noodles. The number of folds increased as 1, 3 and 5 with corresponding decline in the oil absorption i.e 23.63%, 18.84% and 17.29%, respectively. It can be inferred that noodles made from dough sheet with a single fold had maximum oil uptake while the noodles made with maximum number of folds experienced least oil uptake. Alternatively, oil penetration becomes difficult with increased number of folds. The thickness of the dough sheet also showed a considerable association with the oil uptake. The sheet thickness varied from 1 to 2 mm and so the oil uptake from 18.84 to 27.64%, implying that lowest oil uptake was observed in thinner noodles whilst highest oil uptake was observed in thicker noodles. A possible explanation for this could be that thicker noodles exposed smaller areas for moisture removal and so required longer frying times for optimal cooking. Prolonged frying here might be related to higher oil penetration in the noodles. These results were in contradiction to that of Gulia and Khatkar (2013) who reported that higher thickness of sheet resulted in lower oil uptake.

Mahmud, Islam, and Tahergorabi (2023) highlighted the importance of reducing the thickness of the dough sheet to improve the texture of the finished noodles. The curtailment of the sheet thickness should be carried out gradually, preferably 15-33% and not exceeding 50% in one cycle. This will ensure that the previously established gluten structure will be retained, and no disruption

Rajesh Kumar, Bhupendar Singh Khatkar (2025). *Effect of Processing Parameters on Oil Uptake of Instant Fried Noodles.* International Journal of Multidisciplinary Research & Reviews 4(4), 245-259.

occurs. Comprehensively, repeated dough folding and sheeting improved the alignment of starch and gluten network in longitudinal as well as transverse direction (T. Liu, Niu, & Hou, 2020)and reduced the number and length of the pores, which further restricted the oil uptake. In addition, these alterations heightened the hardness and smoothness of the noodles as well as reduced the cooking loss(Y. Li et al., 2024), which could be associated with the increased amount of α-helical and β-sheet structures and decreased proportion of β-turns and random coils which corresponded to stronger gluten network (W. Li, Dobraszczyk, Dias, & Gil, 2006; Y. Li et al., 2024).It has been widely accepted that hand-rolled noodles ranked superior to machine-rolled noodles owing to their better internal structure which developed as a consequence of repeated folding and rolling (Yu et al., 2021).

- **Effect of steaming time on the oil penetration in the instant noodles**

Steaming is the process of spraying water onto the cut noodle strands and allowing them to cook in a steaming tunnel for 2-3 minutes at 98-100 oC temperature. Steaming is considered as an important step in noodle processing as it governed the rate of noodle's rehydration, firmness, viscoelasticity and ease of cooking (Hou, 2001). Steaming time and temperature were valuable factors in deciding the noodle's quality and consumer acceptability.

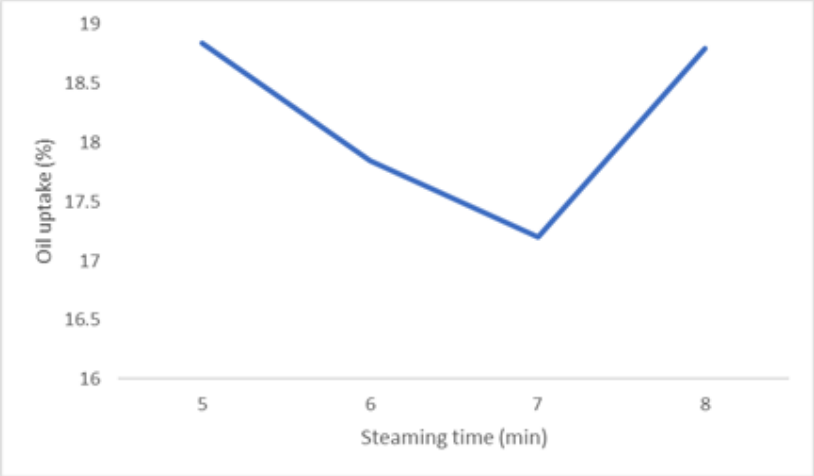

Fig 4: Effect of steaming time on the oil absorption by the instant noodles

Steaming time exhibited a unique relationship with the oil uptake. Initially an inverse trend was observed among these parameters as indicated in Fig 4. As the steaming time increased from 5 to 7 minutes, the oil uptake values declined from 18.84 to 17.2%. However, further exposure to steaming increased the oil uptake and reached a value of 18.8%. This can be attributed to the several physicochemical as well functional changes induced in the starch granules because of heating. As the time period increases, more and more starch crystals get swollen up by absorbing the water and transformed into an amorphous structure from the native granular form (Dhital et al., 2010) The swollen starch molecules occupied the void spaces efficiently which eliminated any weak spots in the gluten structure and resulted in a compact and cohesive gluten matrix.

Rajesh Kumar, Bhupendar Singh Khatkar (2025). *Effect of Processing Parameters on Oil Uptake of Instant Fried Noodles.* International Journal of Multidisciplinary Research & Reviews 4(4), 245-259.

Subsequently, the porosity of the matrix was reduced which limited the oil penetration into the noodles. Apart from the gelatinization process which took place at around 84oC, protein denaturation also occurred during steaming process, but in earlier stage at much lower temperature. An effective steaming ensured maximum gelatinization so that the water absorption capacity of instant noodles was increased (Fu, 2008), cooking loss was minimized (Gatade & Sahoo, 2015), and a mushy and sticky texture was prevented (Sobota, Zarzycki, Kuzawińska, Sykut-Domańska, & Wirkijowska, 2017). Gulia and Khatkar (2013) concluded that sufficient steaming often contributed to an increased cooked weight which remained stable for a considerable period. However, lowering or increasing the steaming time resulted in a lower cooked weight. Noodles undergoing prolonged steaming at lower moisture content may turn out to be drier and crumblier. Similarly, the noodles steamed for a shorter period at higher moisture content resulted in insufficient starch gelatinization. Steaming at optimal moisture content contributed to greater degree of starch gelatinization which produced softer noodles (Hou, 2001).

- **Influence of frying temperature and time on oil uptake by instant noodles**

Once the steaming was completed, the starch was partially gelatinized, and the noodles were almost half-cooked. Followed this is the process of drying which lowered down the moisture content of the instant noodles and ensured their longer shelf-life. The drying could be achieved by air, vacuum drying or deep frying. Deep-frying has been the most suited method for its shorter duration and development of unique golden-brown color in the finished product. In this method, the steamed noodles were subjected to hot oil having temperature around 145 oC and the moisture level dropped from initial 30-40% to final 2-5%. As the hot oil encountered wet noodles, the surface water of the noodles vaporized instantaneously. Due to the imbalance created by the loss of surface water, the water available in interior regions of noodles migrated towards the surface via the channels, leaving behind numerous pores. Ultimately, the oil from the frying medium entered some of these pores, while the remaining empty pores were easily filled by water during rehydration at the time of cooking.

Moreover, the oil absorbed on the surface of noodle strands, eliminated the problem of stickiness in cooked noodles (Hou, 2001). Depending on the noodle strands dimensions and weight, the frying temperature and time varied, which conversely impacted the oil uptake in the noodles. While frying, several physical and chemical reactions including gelatinization of starch, protein denaturation, non-enzymatic reactions (caramelization and Maillard reaction) and absorption of oil occurred, which cumulatively contributed a pleasant golden-brown color and flavor, a porous structure and a crisp texture to the instant noodles (Dehghannya & Ngadi, 2021).

Rajesh Kumar, Bhupendar Singh Khatkar (2025). *Effect of Processing Parameters on Oil Uptake of Instant Fried Noodles.* International Journal of Multidisciplinary Research & Reviews 4(4), 245-259.

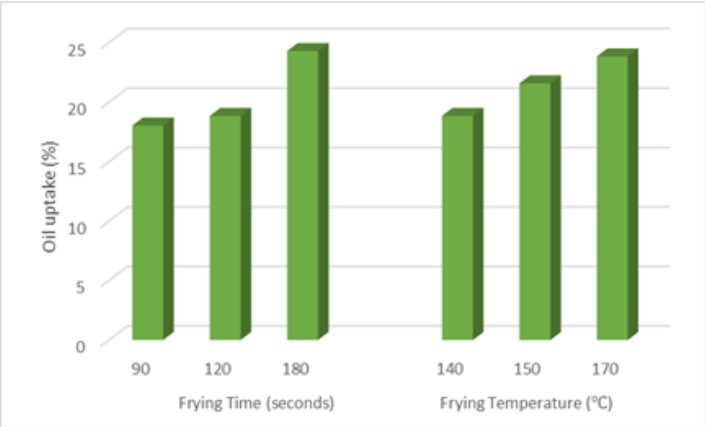

Fig 5: Effect of frying parameters on oil uptake by instant noodles

Frying conditions played an imperative role in governing the oil uptake by instant noodles. Frying time and temperature exhibited a direct correlation with the oil uptake. An increase in frying time from 90, 120 and 180 seconds resulted in greater oil uptake i.e 18.03%, 18.84% and 24.29%, respectively. On the other hand, elevating the frying temperature viz. 140 oC, 150 oC and 170 oC, intensified the oil uptake as well i.e 18.84%, 21.58% and 23.84%, respectively. It can be inferred that frying at lower temperature for shorter duration resulted in noodles with lower oil penetration. Conversely, greasy noodles were obtained when raw noodles were fried at higher temperature for prolonged period. These results were in affirmation to the Gulia and Khatkar (2013)who highlighted that frying temperature and frying time were positively linked with the oil uptake. The underlying reason for this could be that prolonged frying at high temperature tends to remove more amount of water from the instant noodles. The removal of water created several larger pores wherein oil can easily enter and penetrated deep inside, thereby boosting the oil penetration during frying. Moreover, frying temperature and time also had significant influence on the cooking time and cooking loss probably due to their effect on the structure formation in noodles.

4. CONCLUSIONS

The results laid down in the study highlighted the influential role of processing parameters in managing the oil penetration in the instant noodles. Mixing time, dough sheet thickness, frying temperature and frying time exhibited a direct association with the oil uptake. Contrarily, resting time, number of folds and steaming time were inversely related to the oil uptake. The oil uptake in the noodles is dependent on the development of a strong and robust gluten network, which if impaired by any of these parameters will substantially increase the oil penetration. Optimal mixing and resting time along with adequate folding and sheeting ensured formation of uniformly distributed dense gluten network. Steaming and frying, on the other side, have been related to the starch gelatinization and removal of moisture from the noodle strands. The moisture removal created several pores which entrapped oil during frying. Therefore, healthier noodles with reduced oil content could be possible if these processing parameters are carefully optimized.

Rajesh Kumar, Bhupendar Singh Khatkar (2025). *Effect of Processing Parameters on Oil Uptake of Instant Fried Noodles*. International Journal of Multidisciplinary Research & Reviews 4(4), 245-259.

5. AUTHOR(S) CONTRIBUTION

The writers affirm that they have no connections to, or engagement with, any group or body That provides financial or non-financial assistance for the topics or resources covered in this Manuscript.

6. CONFLICTS OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, And/or publication of this article.

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