Organic films develop on indoor surfaces largely through the emission and deposition of semivolatile organic compounds arising from human occupants and consumer products.

on kitchen surfaces, cooking oils age and accumulate after the deposition of large oil droplets and small cooking aerosol particles.

Such films containing unsaturated triglycerides with oleate, linoleate, and linolenate(林呢林-） chains react with ozone

Using oleic acid-based compounds as an example, Figure b (blue section) shows the important steps in ozonolysis. Specifically, this multiphase oxidation pathway proceeds via reactive Criegee（课rain衣） Intermediates (CIs).

Depending on the ambient conditions, the starting lipid may form stable products such as secondary ozonides (SOZs or 1,2,4-trioxolanes) or α-acyloxyalkyl hydroperoxides (α-AAHPs) that contribute to indoor film growth. Meanwhile, the cleavage of carbon−carbon double bonds also emits volatile organic compounds (VOCs) like nonanal, some of which are known respiratory irritants.

With respect to ozone loss, previous measured yields of nonanal emission. its the most abundant indoor VOC (≥3.5% yield) produced by ozonolysis.

another important degradation pathway for cooking oils is Heating. Facilitated by water vapor, a portion of triglycerides decomposes to free fatty acids (e.g., oleic acid) that further react with ozone or hydroxyl radical (OH).

when indoor ozone was sufficiently low, OH-dominated mechanism was suggested. This process is accelerated through cooking with gas stoves, due to the release of nitrogen oxides and nitrous acid (HONO) that enhances the indoor OH level via photodissociation. As shown in the red section of Figure b highlighting the major steps, direct OH oxidation leads to aldehyde formation under elevated NO levels.

high frying temperatures can induce hydrogen abstraction reactions of the triglyceride, following the lipid peroxidation mechanism (black section of Figure b).

//with a focus on the reactive triglycerides, the primary objectives were to

//All predeposited oil coatings were prepared in a chemical laboratory fume hood, and no chemicals were directly used at sampling sites.

//experimental condition：22−24 °C temperature,6−18 ppb ozone, and 20−50% relative humidity / The outdoor weather during the sampling period (up to 8 days) was mostly sunny or partially cloudy with at least 12 h of daylight.

Layout 2目的：As physical barriers, the loosely fitting covers significantly reduced the mass transfer rate of air over the films. This procedure restricted the ozone flow while maintaining a source of oxygen, without further attenuating indoor sunlight.

//this figure presents the NMR spectra of the oil coatings before and after air exposure up to 16 days with signals labeled with A−H corresponding to

the characteristic signals of the unsaturated triglycerides. these oil coatings were placed at a sufficient distance from the active cooking area to avoid additional oil particle.

//The observed formation of SOZs and aldehydes is consistent with the previous study characterizing the products from ozonolysis of pure triolein(try all 林) at elevated relative humidity in a controlled reactor. Hence, in this indoor setting, ozone is the primary oxidant when oil films are exposed to ambient air.

when ozone breaks down the double bond within the linoleate and linolenate(来闹里nate) chains, the resulting intermediate products with 3 or 6 carbons favor volatilization, which in turn makes the SOZ formation pathway less favorable.

//Figure f shows the products accumulated on a clean surface in the proximity of the cooking area (∼1m distance) over a period of 16 days.

the estimated thickness of the collected kitchen film was up to ∼40 nm after 16 days. This is equivalent to a daily growth rate of a few nm, which is at least an order of magnitude larger than the typical reported values on household surfaces, presumably due to the heavy oil consumption and cooking emissions in commercial kitchens.

//Figure b−f shows the (positive ion mode)-ESI mass spectra of canola oil coatings before and after their placement at dark locations.

Figure c,d shows the product composition in the oxidized coating after room air exposure for 4 and 8 days. In accord with the observations at the cafeteria kitchen, the relative signal intensities of the initial triglycerides (m/z 899−903) with respect to the internal standard (m/z 819) decreased over time.

oil degradation was accompanied by new product signals with an additional three oxygens (i.e., Δm/z = 48) that are well-known as SOZs. Together with condensed-phase aldehydes (e.g., m/z 841 and 889), these products are compelling evidence that oil oxidation on the dark bookshelf was driven by ozone.

In contrast, for coatings placed in an enclosed drawer at the same time, the limited air flow and ozone supply were only capable of partially oxidizing oils to SOZs (m/z 951, 999,1047), consistent with an expected lower rate (Figure e,f). In addition, there was a notable formation of products with an additional 2 oxygens (Δm/z = 32), especially after 8 days of placement. As previously discussed, given that oil autoxidation could occur at room temperature, we attribute such oxygenated products to hydroperoxides (ROOH). To confirm their structures, we analyzed the extracted sample in Figure f with a selective MS/MS method for organic hydroperoxide identification.

Lipid autoxidation can also be monitored through ESI-MS in negative ion mode, a sensitive method of detecting hydroperoxides through formate adducts of the molecular ions. As shown in Figure g−i, the process of triglyceride consumption inside the drawer was observed.

a significant amount of the reactive triglycerides (m/z 926−930) was converted into hydroperoxides, whose growth was observed through multiple m/z

additions of 32 after 8 days.

such products were not observed when the oil coating was exposed to room air where ozonolysis dominated

this ionization mode was not sensitive for detecting SOZs

ozone is the primary oxidant in indoor air. However, in enclosed spaces with limited ozone, autoxidation becomes relatively more competitive.

the source of the chemical agents that initiate the radical chain reaction inside the dark drawer is unclear. Two recent studies proposed that trace amounts of reactive gases, metals, or radicals could act as the initiator.

the oil coating was relatively stable in the drawer for the first 4 days (Figure g,h), Müller et al. also observed an induction period in lipid autoxidation.

Lastly, it is likely that the fresh oil in this study already contained a trace amount of hydroperoxides, due to ions at m/z 958 and 960 in Figure g. This is not surprising as oil degradation and hydroperoxide formation during storage has been documented in the literature.

//For this reason, we further investigated the possibility of indoor photooxidation.

To minimize the loss of lipid unsaturation via competing ozonolysis, we optimized the sampling setup by loosely covering the oil coatings with transparent Petri dish covers.

the bis-allylic proton signals (2.77 and 2.80 ppm) disappear，without notable new signals of secondary ozonides at 5.14 and5.19 ppm,

this result indicates that oil degradation was dominated by peroxidation rather than ozonolysis

//further characterized the photochemical aging process through (negative ion mode) ESI-MS，due to the weak product signals in NMR spectra,.

Figure a−c shows that the irradiated coatings underwent rapid triglyceride degradation in 4 days (m/z 924−930 highlighted in yellow) .Meanwhile, higher molecular-weight products were observed through the new signals marked with m/z increments of 32.

This chemical transformation is in stark contrast to the identical sample kept on a dark bookshelf (Figure d), which remained relatively intact for at least 4 days. After this induction period (诱导期), however, the covered coating on the dark bookshelf underwent autoxidation (Figure e,f). This observation was consistent with the uncovered coatings placed inside the drawer described in the previous section.

When light was blocked at the window location, the oil remained inactive for 4 days, indicating that a warmer temperature by the window did not trigger

peroxidation. Generally, it is believed that lipid photooxidation is driven by photosensitizers in cooking oils (叶绿素), leading to photosensitized oxidation.

在光照射后，被激活的光敏剂可以:(i)从脂质中提取氢原子或(ii)与分子氧发生反应。即使没有光敏剂的作用，室内阳光也是引发过氧化反应的强诱因（其他实验证明)。

//Unsaturated oils chemical fates can be characterized through two major multiphase oxidation pathways.

(1) This rapid chemical transformation makes the films highly dynamic, affecting the surface reactivity.(在不过度暴露于高温或阳光下的情况下，即使在较高的相对湿度下，高粘性SOZs也能保持高稳定性12天、72天至88个月由于这个原因，活性表面污染物在SOZs覆盖下可能有更长的寿命。)Further epidemiological studies are needed to better evaluate the underlying health impacts.