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Nutritional Variation in Bagrid Catfish *Chrysichthys nigrodigitatus* (Lacépède, 1803) with Processing Methods

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Abstract: The Bagrid Catfish, *Chrysichthys nigrodigitatus*, is an important source of animal protein for the West African population. The nutritional profile of *C. nigrodigitatus* as raw and processed parts was investigated using standard techniques. For the fish head, the proximate parameters increased significantly ($P<0.05$) in values with the processing with smoked fish head having the highest crude protein (29.60±1.49 %), crude fat (23.09±1.04 %) and total ash (23.22±1.53 %) while fried fish head exhibited the highest carbohydrate value of 30.37±0.43 % compared. which shows the fish flesh proximate composition, revealed a significant reduction (P<0.05) in moisture content after processing from 78.15±0.29 % in the raw fish to 54.98±0.14 and 23.61±5.07 in fried and smoked fish respectively. In the proximate composition of the fish tail (Table 3), the crude protein (12.77±0.34 %), fat (2.49±0.48 %) and ash contents (0.92±0.4 %) for raw sample were the lowest compared to that of the processed fish. Smoking in raw fish head had a significant increase in sodium and magnesium with values of 243.43±10.07 and 33.26±2.52 respectively. This correlation matrix showed some important relationships between the proximate composition and mineral content analyzed. Negative relationship was not observed in most of the correlation matrixes for both raw and processed fish samples. It is therefore better to process Bagrid fish using smoking method as fish preserved using these preservation methods have better protein content.

1. Introduction

Fish is a good source of protein, vitamins, and minerals. The nutritional characteristics of fish and fishery products are of vital interest to consumers. The nutritional value of fish comprises the contents of moisture, dry matter, protein, lipids, vitamin and minerals plus the caloric value, while minerals are essential nutrient components of many enzymes and metabolism and it contributes to the growth of fish itself (Opeyemi, 2020). Different parts of fish have different nutritional values. Fish fillet is a good source of protein and omega-3 fatty acids, while fish liver is rich in vitamin A and D. Fish head and roe are also good sources of protein and minerals, and fish bones are a good source of calcium. Fish is a highly nutritious food that is rich in protein, omega-3 fatty acids, vitamins, and minerals.

Fish fillet is a popular and widely consumed part of fish. It is the flesh of the fish without the bones and skin. Fish fillet is a good source of protein, omega-3 fatty acids, vitamins B12, D, and minerals such as calcium, iron, and zinc. According to the USDA, a 3-ounce serving of cooked fish fillet contains approximately 20 grams of protein, 3 grams of fat, and 85-130 calories, depending on the species of fish. Fish head is also consumed in some cultures. It is a good source of protein, omega-3 fatty acids, and minerals such as calcium and phosphorus. According to the USDA, a 3-ounce serving of cooked fish head contains approximately 15 grams of protein, 5 grams of fat, and 105-135 calories, depending on the species of fish.

However, the nutritional values of fish can be affected by different processing methods, but fish remains a highly nutritious food regardless of the processing method. The oldest and most widely practiced form of fish processing particularly in the tropics is smoke drying (Ogunbambo and Akinleye, 2022). Smoke-drying is the main traditional processing method used in extending fish shelf life in Nigeria with a percentage of about 45 % as against 27 % eaten fresh (Amponsah *et al*., 2022). Smoke dried fish is an integral part of the diet of many Nigerians and processing by smoke-drying is the main source of income for many people, especially in rural areas (Ogunbambo, 2019). Canned, smoked, frozen, and dried fish are still good sources of protein and omega-3 fatty acids, but may have lower levels of certain nutrients such as vitamin C and thiamin.

Bagrid Catfish, *Chrysichthys nigrodigitatus*, is an important source of animal protein for the West African population. It is a freshwater fish species that is commonly found in the Niger Delta region of Nigeria and other African countries. The nutritional composition of this fish varies with age, size, sex, and location of capture. The proximate composition of *C. nigrodigitatus* has been reported by several researchers. For instance, a study by Olowu *et al*. (2011) reported that the fish contains 77.89 % moisture, 17.43 % protein, 1.52 % fat, 1.13% ash, and 1.03 % fiber. Another study by Adeyeye *et al.* (2012) found that the fish contains 72.30 % moisture, 17.30 % protein, 2.75 % fat, 2.65 % ash, and 2.00 % fiber. These studies suggest that *C. nigrodigitatus* is a good source of protein and has low-fat content.

In addition to protein and fat, *C. nigrodigitatus* also contains vitamins and minerals. A study by Obiekezie *et al*. (2015) reported that the fish contains significant amounts of vitamins A, B1, B2, B3, and C. The study also found that the fish is rich in minerals such as calcium, phosphorus, magnesium, and potassium. The nutritional value of *C. nigrodigitatus* makes it a healthy food option. It is especially important for people in the West African region who may not have access to other sources of protein. However, it is important to note that the fish can accumulate toxins such as mercury, which can be harmful to human health. Therefore, it is important to consume the fish in moderation and to ensure that it is properly cooked before consumption.

Previous workers had reported the effects of some processing methods on different fish types. There seems to be a scarcity of information on the effect of processing methods on the nutritive value of different parts of fish, thus this study investigates the effect of processing methods on the nutritive value of different part of *C. nigrodigitatus*.

2. Methodology

2.1 Sourcing and preparation of samples

The Bagrid catfish samples used in this study were obtained from Makoko Fish Market in Lagos State-Nigeria. They were gutted, thoroughly washed using clean tap water, cut into about 50g-pieces and washed again with tap water. The samples were then separated into three parts (flesh, head and tail) and three different portions where one portion was analyzed raw; second was smoked while the third portion was deep-fried with vegetable oil in a frying pan. Boiling was done in distilled water, kept boiling for about 20 minutes until the pieces were cooked and tender. Smoking was carried out using traditional Drum kiln at a temperature range of 60 - 85^{0}C with the aid of temperature alarm. The fish smoking continues until fairly constant weight was achieved. Frying was achieved within 15 minutes and the temperature was about 240°C. All processing methods followed the usual procedures used to prepare fish for table consumption in Nigeria but without the addition of any ingredient. All samples were homogenized prior to analysis.

Photo 1: Bagrid catfish samples used

2.2 Analytical procedures

The determination of the percentage proximate composition was analyzed chemically according to the method of analysis described by the Association of Official Analytical Chemist (AOAC, 2006). For the moisture content, fish muscle triplicate samples were kept in an oven, at 102-105°C for 24 h. The ash content was determined by incineration of 5 g of the sample at 600°C for 8 hours. The determination of crude fat content was conducted by soxhlet extraction method using n-hexane as solvent. The N-content was multiplied by 6.25 to estimate the protein of the samples.

Mineral components were evaluated from solution obtained by first wet-ashing the samples and dissolving the ash with de-ionized water and concentrated hydrochloride acid in standard flask. The solution was analyzed for minerals content using Atomic Absorption Spectrophotometer. Phosphorus was analyzed for by employing the method reported by Vanado Molybate and read on colorimeter.

2.3 Statistical analysis

Data were analyzed by descriptive analysis and Duncam multiple range test (DRMT). SPSS (version 17.0) statistical software package (SPSS, Chicago, USA) was employed in the analysis. Differences were considered significant at an alpha level of 0.05. All means were given with ± standard error.

3. Results and Discussion

3.1 Proximate composition

The proximate composition of different part of raw and processed Bagrid Catfish are shown in **Table 1** to **Table 3**. For the fish head, the proximate parameters increased significantly (P<0.05) in values with the processing with smoked fish head having the highest crude protein (29.60±1.49 %), crude fat (23.09±1.04 %) and total ash (23.22±1.53 %) while fried fish head exhibited the highest carbohydrate value of 30.37±0.43 % compared. The higher protein and lipid content of the processed samples reveals their involvement in energy production at cellular level (Lawal-Are *et al*., 2018).

Table 2. which shows the fish flesh proximate composition, revealed a significant reduction (P<0.05) in moisture content after processing from 78.15±0.29 % in the raw fish to 54.98±0.14 and 23.61±5.07 in fried and smoked fish respectively. However, crude protein content increased from 7.03±0.22 (raw) to 30.25±0.23 (fried) and subsequently 42.06±5.85 (smoked). There was no significant difference in fat content while crude fibre was not detected. These results are similar to the values reported for flesh of *Pandalus borealis* from Lagos Atlantic Ocean (Adeyeye *et al*., 2016).

Table 1. Proximate composition (%) of raw and processed fish **head**

Parameters	Raw	Smoked	Fried
Moisture	79.61±0.23^{a}	9.32±0.82^{b}	20.19±1.15^{c}
Crude Protein	16.11±0.07^{a}	29.60±1.49^{b}	16.64±0.52^{a}
Fat	3.22±0.21^{a}	23.09±1.04^{b}	22.47±0.86^{b}
Crude Fibre	ND	ND	ND
Ash	0.84±0.06^{a}	23.22±1.53^{b}	10.33±1.55^{b}
Carbohydrate	0.22±0.01^{a}	14.77±0.56^{b}	30.37±0.43^{c}

Keys: Mean±Standard Error; ND= Not detected; Values with different superscripts across row are significantly different at ($P < 0.05$) ; NFE: Nitrogen Free Extract (Carbohydrate CH

Table 2. Proximate composition (%) of raw and processed fish **flesh**

Parameters	Raw	Smoked	Fried
Moisture	78.15±0.29^{a}	23.61±5.07^{b}	54.98±0.14^{b}
Crude Protein %	7.03±0.22^{a}	42.06±5.85^{b}	30.25±0.23^{b}
Fat	11.08±0.18^{a}	14.47±0.47^{a}	11.86±0.31^{a}
Crude Fibre	ND	ND	ND
Ash %	1.99±0.06^{a}	6.97±0.55^{b}	1.99±0.38^{a}
NFE	1.75±0.23^{a}	12.89±0.23^{b}	0.92±0.01^{c}

Keys: Mean±Standard Error; ND= Not detected; Values with different superscripts across row are significantly different at ($P < 0.05$) ; NFE: Nitrogen Free Extract (Carbohydrate)

In the proximate composition of the fish tail (**Table 3**), the crude protein (12.77±0.34 %), fat (2.49±0.48 %) and ash contents (0.92±0.4 %) for raw sample were the lowest compared to that of the processed fish. Ayeloja *et al.* (2019) reported similar result in their study of the effect of processing methods on nutritive value of yellow croaker (*Larimichthys polyactis*).

Table 3. Proximate composition (%) of raw and processed fish **tail**

Parameters	Raw	Smoked	Fried
Moisture	82.62±1.13^{a}	31.77±1.54^{b}	63.03±0.90^{c}
Crude Protein	12.77±0.34^{a}	40.35±0.85^{b}	20.29±0.77^{c}
Fat	2.49±0.48^{a}	14.44±0.40^{b}	8.78±0.23^{c}
Crude Fibre	ND	ND	ND
Ash	0.92±0.4^{a}	5.02±0.06^{b}	2.13±0.02^{c}
NFE	1.2±0.24^{a}	8.42±0.036^{b}	5.77±0.09^{c}

Keys: Mean±Standard Error; ND= Not detected; Values with different superscripts across row are significantly different at ($P < 0.05$); NFE: Nitrogen Free Extract (Carbohydrate CHO)

3.2 Mineral profile

The mineral content of different part of raw and processed Bagrid Catfish are shown in **Table 4** to **Table 6**. The result conforms to the report of which indicates that the marine fish can be a good source of macro minerals (Na, K, Ca and Mg) and of micro mineral (especially Zinc) for human health

(Wardiatno *et al*., 2012). In the present work, raw fish head sample has the highest mg/100g levels of calcium, potassium and phosphorus as follows: 112.56±1.47, 410.65±3.85 and 268.67±4.01 respectively. Smoking had a significant increase in sodium and magnesium with values of 243.43±10.07 and 33.26±2.52 respectively. **Table 5.** which shows the fish flesh mineral content, revealed a significant reduction (after processing) in calcium, potassium and magnesium from 163.27±0.48 mg/100g, 694.43±3.75 mg/100g and 210.16±3.23 mg/100g respectively. There was no significant difference in calcium and magnesium content of smoked and fried samples.

Table 4. Mineral concentration (mg/100g) of raw and processed fish **head**

Parameters (mg/100g)	Raw	Smoked	Fried
Calcium	112.56 ± 1.47^a	104.64 ± 7.77^a	100.17 ± 4.05^a
Sodium	66.89 ± 0.07^a	243.43 ± 10.07^b	19.34 ± 0.54^c
Potassium	410.65 ± 3.85^a	305.43 ± 6.45^b	136.49 ± 2.33^c
Magnesium	22.45 ± 0.06^a	33.26 ± 2.52^a	17.15 ± 1.55^a
Phosphorus	268.67 ± 4.01^a	174.49 ± 7.76^b	106.54 ± 4.67^c

Keys: Mean±S.E; Values with different superscripts across row are significantly different at (P < 0.05)

Table 5. Mineral concentration (mg/100g) of raw and processed fish **flesh**

Parameters (mg/100g)	Raw	Smoked	Fried
Calcium	163.27 ± 0.48^a	48.54 ± 5.70^b	84.96 ± 1.47^b
Sodium	58.65 ± 0.25^a	321.56 ± 5.14^b	23.67 ± 0.96^c
Potassium	694.43 ± 3.75^a	207.25 ± 3.09^b	110.32 ± 0.84^c
Magnesium	36.70 ± 0.06^a	14.90 ± 2.10^b	11.23 ± 0.01^b
Phosphorus	210.16 ± 3.23^a	221.45 ± 2.31^a	121.82 ± 5.14^b

Keys: Mean±S.E; Values with different superscripts across row are significantly different at (P < 0.05)

With the exception of sodium in the mineral content of the fish tail (**Table 6**), raw samples had the highest mineral content value of 144.45±5.63, 488.11±4.96, 20.09±0.40 and 255.40±5.60 for calcium, potassium, magnesium and phosphorus respectively.

Table 6. Mineral concentration (mg/100g) of raw and processed fish **tail**

Parameters (mg/100g)	Raw	Smoked	Fried
Calcium	144.45 ± 5.63^a	79.21 ± 1.55^b	96.42 ± 1.41^c
Sodium	60.73 ± 0.36^a	344.16 ± 5.51^b	21.54 ± 1.03^c
Potassium	488.11 ± 4.96^a	207.34 ± 3.96^b	119.96 ± 0.72^c
Magnesium	20.09 ± 0.40^a	14.07 ± 0.06^b	11.09 ± 0.02^c
Phosphorus	255.40 ± 5.60^a	218.64 ± 0.36^b	120.41 ± 1.01^c

Keys: Mean±S.E; Values with different superscripts across row are significantly different at (P < 0.05)

3.3 Relationship matrix

The relationship matrix in the nutrient composition of different part of raw and processed Bagrid Catfish are shown from **Table 7** to **Table 15.** Similar to the report of Lawal-Are *et al*. (2018) on Guinean Mantis Shrimp from Lagos Lagoon, negative relationship was not observed in most of the correlation matrixes for both raw and processed fish samples. This correlation matrix showed some important relationships between the proximate composition and mineral content analyzed. **Table 7** showed the correlation matrix for smoked fish head in which case there were approximately perfect positive relationships between total ash/ carbohydrate and all the mineral parameters. Similar relationship was exhibited by fat/carbohydrate with all mineral parameters in smoked fish flesh (**Table 8**). For smoked fish tail, only moisture content showed negative relationship with all the mineral elements (**Table 9**).

Table 7. Correlation coefficient among the proximate and mineral compositions of smoked fish head

	Moist	*CP*	*Fat*	*Ash*	*NFE*	*Ca*	*Na*	*k*	*Mg*	*P*
Moist	1									
CP	-0.50	1								
Fat	0.83	0.07	1							
Ash	-0.48	-0.52	-0.89	1						
NFE	-0.34	-0.64	-0.81	0.99	1					
Ca	-0.25	-0.71	-0.75	0.97	1.00	1				
Na	-0.19	-0.75	-0.71	0.95	0.99	1.00	1			
K	0.08	-0.90	-0.49	0.83	0.91	0.94	0.96	1		
Mg	-0.41	-0.58	-0.85	1.00	1.00	0.99	0.97	0.87	1	
P	-0.13	-0.79	-0.66	0.93	0.98	0.99	1.00	0.98	0.96	1

Table 8. Correlation coefficient among the proximate and mineral compositions of smoked fish flesh

	Moist	*CP*	*Fat*	*Ash*	*NFE*	*Ca*	*Na*	*k*	*Mg*	*P*
Moist	1									
CP	-1.00	1.00								
Fat	0.93	-0.92	1.00							
Ash	0.34	-0.37	-0.02	1.00						
NFE	0.66	-0.64	0.89	-0.48	1.00					
Ca	1.00	-1.00	0.95	0.28	0.71	1.00				
Na	1.00	-0.99	0.96	0.25	0.73	1.00	1.00			
K	1.00	-1.00	0.95	0.30	0.70	1.00	1.00	1.00		
Mg	1.00	-1.00	0.95	0.30	0.69	1.00	1.00	1.00	1.00	
P	0.81	-0.79	0.97	-0.27	0.98	0.85	0.86	0.84	0.83	1

Table 10 showed the correlation matrix for fried fish head in which case there were approximately perfect positive relationships between crude protein/total ash and all the mineral elements. Similar relationship was exhibited by fat/carbohydrate with all mineral parameters in fried fish flesh (**Table 11**). For fried fish tail, only moisture content showed negative relationship with all the mineral elements (**Table 12**).

Table 9. Correlation coefficient among the proximate and mineral compositions of smoked fish tail

	Moist	*CP*	*Fat*	*Ash*	*NFE*	*Ca*	*Na*	*k*	*Mg*	*P*
Moist	1									
CP	-0.93	1.00								
Fat	-0.89	0.65	1.00							
Ash	-0.78	0.49	0.98	1.00						
NFE	-0.96	0.78	0.98	0.93	1.00					
Ca	-0.90	0.66	1.00	0.98	0.99	1.00				
Na	-0.94	0.73	0.99	0.95	1.00	1.00	1.00			
K	-1.00	0.91	0.91	0.80	0.97	0.91	0.95	1.00		
Mg	-0.78	0.49	0.98	1.00	0.93	0.98	0.95	0.80	1.00	
P	-0.96	0.78	0.98	0.93	1.00	0.99	1.00	0.97	0.93	1

Table 10. Correlation coefficient among the proximate and mineral compositions of fried fish head

	Moist	*CP*	*Fat*	*Ash*	*NFE*	*Ca*	*Na*	*k*	*Mg*	*P*
Moist	1									
CP	-0.50	1.00								
Fat	0.35	-0.99	1.00							
Ash	-0.87	0.86	-0.77	1.00						
NFE	0.38	-0.99	1.00	-0.78	1.00					
Ca	-0.78	0.93	-0.86	0.99	-0.87	1.00				
Na	-0.50	1.00	-0.99	0.86	-0.99	0.93	1.00			
K	-0.68	0.98	-0.93	0.95	-0.94	0.99	0.98	1.00		
Mg	-0.87	0.86	-0.77	1.00	-0.78	0.99	0.86	0.95	1.00	
P	-0.89	0.84	-0.74	1.00	-0.76	0.98	0.84	0.94	1.00	1

Table 11. Correlation coefficient among the proximate and mineral compositions of fried fish flesh

	Moist	*CP*	*Fat*	*Ash*	*NFE*	*Ca*	*Na*	*k*	*Mg*	*P*
Moist	1									
CP	-0.12	1.00								
Fat	0.84	-0.65	1.00							
Ash	-0.99	0.00	-0.76	1.00						
NFE	0.59	-0.87	0.94	-0.49	1.00					
Ca	0.87	-0.59	1.00	-0.81	0.91	1.00				
Na	0.68	-0.81	0.97	-0.58	0.99	0.95	1.00			
K	0.99	-0.25	0.90	-0.97	0.69	0.93	0.77	1.00		
Mg	0.59	-0.87	0.94	-0.49	1.00	0.91	0.99	0.69	1.00	
P	0.98	-0.31	0.92	-0.95	0.73	0.95	0.80	1.00	0.73	1

Table 13 showed the correlation matrix for raw fish head in which case there were approximately perfect positive relationships between crude protein/total ash/carbohydrate and all the mineral parameters. Similar relationship was exhibited by crude protein/total ash/carbohydrate with all mineral parameters in raw fish flesh (**Table 14**). For raw fish tail, there were positive relationships between crude protein/total ash/carbohydrate and all the mineral elements (**Table 15**).

Table 12. Correlation coefficient among the proximate and mineral compositions of fried fish tail

	Moist	*CP*	*Fat*	*Ash*	*NFE*	*Ca*	*Na*	*k*	*Mg*	*P*
Moist	1									
CP	-0.93	1								
Fat	-0.5	0.15	1							
Ash	-0.94	0.76	0.76	1						
NFE	-0.63	0.31	0.99	0.85	1					
Ca	-1.00	0.93	0.5	0.95	0.64	1				
Na	-0.98	0.83	0.67	0.99	0.79	0.98	1			
K	-0.96	0.79	0.72	1.00	0.83	0.96	1	1		
Mg	-0.94	0.76	0.76	1.00	0.85	0.95	0.99	1.00	1	
P	-0.86	0.62	0.87	0.98	0.94	0.87	0.95	0.97	0.98	1

Table 13. Correlation coefficient among the proximate and mineral compositions of raw fish head

	Moist	*CP*	*Fat*	*Ash*	*NFE*	*Ca*	*Na*	*k*	*Mg*	*P*
Moist	1									
CP	-0.09	1.00								
Fat	-0.83	-0.48	1.00							
Ash	-0.84	0.62	0.38	1.00						
NFE	-0.03	1.00	-0.54	0.57	1.00					
Ca	-0.21	0.99	-0.37	0.71	0.98	1.00				
Na	-0.09	1.00	-0.48	0.62	1.00	0.99	1.00			
K	-0.86	0.58	0.43	1.00	0.52	0.67	0.58	1.00		
Mg	-0.84	0.62	0.38	1.00	0.57	0.71	0.62	1.00	1.00	
P	-0.52	0.90	-0.05	0.90	0.87	0.94	0.90	0.88	0.90	1

Table 14. Correlation coefficient among the proximate and mineral compositions of raw fish flesh

	Moist	*CP*	*Fat*	*Ash*	*NFE*	*Ca*	*Na*	*k*	*Mg*	*P*
Moist	1									
CP	-0.63	1.00								
Fat	0.72	-0.99	1.00							
Ash	-0.99	0.52	-0.61	1.00						
NFE	-0.99	0.52	-0.61	1.00	1.00					
Ca	-0.95	0.84	-0.90	0.90	0.90	1.00				
Na	-0.63	1.00	-0.99	0.52	0.52	0.84	1.00			
K	-0.88	0.92	-0.96	0.81	0.81	0.98	0.92	1.00		
Mg	-0.99	0.52	-0.61	1.00	1.00	0.90	0.52	0.81	1.00	
P	-0.86	0.94	-0.97	0.79	0.79	0.98	0.94	1.00	0.79	1

Table 15 Correlation coefficient among the proximate and mineral compositions of raw fish tail

	Moist	*CP*	*Fat*	*Ash*	*NFE*	*Ca*	*Na*	*k*	*Mg*	*P*
Moist	1									
CP	-0.20	1.00								
Fat	-0.95	-0.13	1.00							
Ash	-0.93	-0.18	1.00	1.00						
NFE	-0.99	0.06	0.98	0.97	1.00					

Ca	-0.61	-0.66	0.83	0.86	0.71	1.00				
Na	-0.85	-0.35	0.97	0.98	0.91	0.94	1.00			
K	-0.80	-0.44	0.95	0.96	0.87	0.97	1.00	1.00		
Mg	-0.93	-0.18	1.00	1.00	0.97	0.86	0.98	0.96	1.00	
P	-0.96	-0.10	1.00	1.00	0.99	0.81	0.97	0.94	1.00	1

Conclusion

The present study provides information on the nutritional composition of Bagrid Catfish with processing methods. The catfish is a fantastic source of proximate and minerals according to the study. The information from this study could be used as a starting point for future research. The study suggests that this species is ideally suited as a raw ingredient in the culinary business. On the other hand, smoked fish had the highest crude protein and fat followed by fried fish. Smoked fish had the highest percentage of ash which probably resulted from the burnt organic matter; this signifies that the smoked fish products had high levels of mineral matter. It is therefore better to process Bagrid fish using smoking method as fish preserved using these preservation methods have better protein content. Negative relationship was not observed in most of the correlation matrixes for both raw and processed fish samples.

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Compliance with Ethical Standards: This article does not contain any studies involving human or animal subjects.

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