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Effects of Feeding Ponderosa Pine Needles During Pregnancy: Comparative Studies with Bison, Cattle, Goats, and Sheep[1]

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ABSTRACT: Four experiments were conducted to determine the effect of feeding dried pine needles (*Pinus ponderosa*; PN) on the abortion rate of ruminants. In Exp. 1, cattle were fed 5.4 kg of PN daily for 21 d starting at 116, 167, 215, or 254 d of pregnancy. The PN did not cause abortions when started at 116 d; thereafter, the percentage of cows that aborted increased linearly, and the interval to abortion decreased linearly (both $P < .01$); all cows fed PN beginning at 254 d aborted. In Exp. 2, cattle were fed .7, 1.4, or 2.7 kg of PN for 21 d or 2.7 kg for 1 or 3 d. Sheep and goats were fed .8 and .5 kg of PN, respectively, starting at 121 d of pregnancy. The PN induced some abortions in cattle when fed for 1 (11%) or 3 (30%) d, but the abortion rate was greater ($P < .01$) when the PN were fed for longer periods of time (80, 90, and 100% aborted in 19, 17, and 10 d for .7-, 1.4-, and 2.7-kg doses, respectively). No goats or sheep aborted in response to PN feeding. Pregnancy rates during the next breeding season for cows that aborted in response to the PN were slightly higher than rates for control cows (94 vs 87%). In Exp. 3, buffalo (*Bison bison*) and cattle were fed 2.25 kg of PN from the same collection. Abortions were induced in all buffalo and cattle that were fed PN. In Exp. 4, low amounts (.11 and .34 kg) of PN were fed to cattle for 40 d before the start of feeding of 1.35 kg of PN at 255 d of pregnancy. Low amounts of PN did not induce abortions, but .34 kg delayed abortions after the 1.35-kg level was fed ($P < .01$). In all experiments aborted fetuses were alive, all cows (both buffalo and cattle) that aborted had a retained placenta, and calf survival was dependent on maturity at the time of parturition. Our conclusions are as follows: 1) consumption of PN caused abortions in a majority of cows in late pregnancy; 2) the response increased with advancing stage of pregnancy, increased dose of PN, and greater length of exposure, but supplemental vitamin A was not prophylactic; 3) buffalo responded similarly to cattle, but neither goats nor sheep were affected by PN; 4) fertility was not affected by PN; 5) PN were not directly toxic to calves, and survival of calves was dependent on maturity at the time of parturition; and 6) compensatory mechanisms were triggered when subthreshold doses of PN were fed.

Key Words: Ruminants, Abortion, *Pinus ponderosa*, Pine Needles, Dosage, Gestation Period

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Introduction

Abortions and related problems caused by cows eating needles from Ponderosa pine (*Pinus ponderosa*) trees (Bruce, 1927; MacDonald, 1952; James et al., 1989) result in multimillion dollar losses each year to the beef cattle industry in the western United States (Lacey et al., 1988). Losses are caused by retention of the placenta, death of premature calves, and lowered subsequent fertility of the dam (James et al., 1989). It is not known whether lowered fertility is a direct effect of the pine needles or an indirect effect through complications related to retained placenta. Likewise, the abortive mechanism of action is not completely understood, although it is known that consumption of pine needles decreases blood flow to the uterus (Christenson et al., 1992a,b; Ford et al., 1992).

The incidence of abortions caused by consumption of pine needles in cattle under ranching conditions is highly variable (James et al., 1989). There is little indication from field data of the cause of this variability, except that some ranchers have reported that injecting vitamin A or altering supplemental feeding practices will prevent the effects of pine needles. Both fresh and dried needles will cause abortions, season of needle collection makes no difference, and the effect is pharmacological rather than pathological (Jensen et al., 1989; Stuart et al., 1989; Panter et al., 1991).

Little is known about the effects of pine needles in grazing species other than cattle. Deer consume high levels of Ponderosa pine needles with no effects on fawning rates (Nellis, 1968; Currie et al., 1977; Dusek, 1980). Buffalo (*Bison bison*) grazing in areas with Ponderosa pine have no unusual incidence of abortions at the Windcave National Park and Custer State Park in southwest South Dakota[2]. There have been field reports of abortions caused by PN in goats and sheep, but experimental data do not agree with those observations (Panter et al., 1987; James et al., 1989).

Four experiments were conducted to determine the effects of several variables on the response to feeding PN during pregnancy. Specific objectives for each experiment are addressed in the Materials and Methods section.

Materials and Methods

Pine needles were collected from mature Ponderosa pine (*Pinus ponderosa*) trees in Custer County, MT. Live trees were cut during the winter. Needles were collected by stripping at the time the trees were cut or by cutting branches and stripping needles after they were allowed to dry. Air-dried needles were ground through a hammermill with a 2.25-cm screen and mixed with ground hay at the time of feeding. Amounts of pine needles and hay fed are reported herein on an air-dry basis. Cows fed pine needles were injected with 20 mL of an antibiotic (Penstrep®, Durvet, Blue Springs, MO) each day for 3 d after calving to prevent complications from retained placenta. The cattle were multiparous Hereford or crossbred (various combinations of Hereford, Angus, Red Angus, Charolais, or Simmental) cows that weighed from 450 to 675 kg. Breeding dates were known so that the feeding of pine needles could be started at specified times in relationship to anticipated parturition. Statistical comparisons were made by chi-square for discrete data and with ANOVA for continuous data using single df contrasts in an unweighted means analysis.

Experiment 1

This experiment was conducted to determine the effect of stage of pregnancy on parturition response to the feeding of pine needles. Cows were bred at a synchronized estrus at one of four different times during the year so that four stages of pregnancy would be represented on a given date in the fall. The average number of days after breeding (stage of pregnancy) of the four groups at the start of feeding pine needles was 116 ± .9, 157 ± .8, 207 ± .8, and 254 ± 0. Cows were group-fed a diet consisting of 50% ground pine needles and 50% ground alfalfa hay. The total diet per cow was 5.4 kg/d, and it was fed for 21 d, or until parturition.

Experiment 2

This experiment was conducted to determine the effects of varying the amount and duration of feeding pine needles in cattle, to determine whether an injection of vitamin A would affect the response to pine needles, to determine the effect of consumption of pine needles on subsequent fertility, and to compare the response in cattle to goats and sheep when all were fed pine needles from the same collection.

Sixty-nine cows were assigned at random to one of seven treatments summarized in Table 1. The experimental treatments were started approximately every 10 d during February and March so

[2]Personal communications from Ron Walker, resource program manager, Custer State Park and Larry Hays, resource management specialist, Windcave National Park.

Table 1. Effects of feeding pine needles (PN) on pregnancy maintenance in cattle, sheep, and goats (Exp. 2)

Species and treatment[a]	No. of animals	PN fed, kg	No. of days fed PN	Percentage aborted	Interval to parturition, d[b]
Cattle					
Control	14	0	0	0	33
.7 PN	10	.7	21	80	19
1.4 PN	10	1.4	21	90	17
2.7 PN	10	2.7	21	100	10
PN, 3	10	2.7	3	30	26
PN, 1	9	2.7	1	11	34
PN + VA	6	2.7	14	83	11
					(8.7)
Sheep					
Control	9	0	0	0	27
PN	9	.8	14	0	27
					(1.8)
Goats					
Control	11	0	0	9	28
PN	7	.5	14	0	28
					(5.7)

[a]Treatment abbreviations refer to amount or days of feeding of PN; VA was a 4.5 million IU injection of vitamin A before PN feeding started.
[b]Pooled SE are shown in parentheses for each species.

that each cow was at 250 d (range = 245 to 255 d) of pregnancy at the start of treatment. Vitamin A (4.5×10^6 IU total) was injected 1 wk before pine needles were fed (2.25×10^6 IU) and at the time that feeding of pine needles started (2.25×10^6 IU). The amount of pine needles fed and the duration of feeding were varied as shown in Table 1. The total diet fed per cow was always 5.4 kg/d, and the amount of hay fed was adjusted to maintain that total amount. All cows that were nursing a calf were bred by AI during the subsequent 45-d breeding season. Cows that had calves that died were sold or were not included in the pregnancy data to avoid confounding breeding performance with suckling status. Pregnancy was confirmed by rectal palpation at weaning the next fall.

Eighteen white-faced sheep (66 ± 8 kg) and 18 Spanish-type goats (35 ± 4 kg) that were diagnosed as pregnant in the fall from a synchronized estrus were assigned at random to be controls or to be fed pine needles as shown in Table 1. The treatments were started on March 12 at 121 d (range = 117 to 125) of pregnancy in sheep and on February 5 at 121 or 122 d of pregnancy in goats. Pine needles fed to goats and sheep were from the same batch as those fed to cattle in this experiment.

Experiment 3

This experiment was conducted to determine whether buffalo would abort after eating pine needles from the same collection as that fed to cattle. The portion of this experiment involving buffalo was conducted at the National Bison Range, Moise, MT. The pastures used by buffalo at this location include Ponderosa pine at higher elevations and on southern slopes. No problems with calving rates or abortions had been observed. Cows in this herd normally calve in late April and early May. Exact breeding dates are not known because bulls were pastured with cows year-round. Buffalo in this area are short-season breeders, and most breeding activity is observed in late July and August. A herd of buffalo was rounded up on April 1, and on April 2, cows were rectally palpated for pregnancy. The first 12 that were confirmed to be pregnant were assigned at random to be fed ground pine needles and hay (six animals) or fed a control diet of hay only (six animals). Cow age was estimated to range from 3 to 8 yr, and the estimated stage of pregnancy was 230 to 260 d. On April 2, both groups were group-fed 9 kg per animal of hay, and no feed was given on the following day to facilitate eating of the subsequent diets. The experimental rations were started on April 4. The control group was group-fed baled hay each day at the rate of 9 kg per animal throughout the experiment. The cows fed pine needles were also group-fed, and on the 1st d of feeding they received .45 kg per animal of ground pine needles. This amount was increased each day by .22 kg until each received 2.25 kg/d of pine needles. The amount of hay fed each day was decreased so that the total ration was always 9 kg per animal. The experimental rations were continued until cows aborted or calved, at which time

they were removed from the experiment and placed with the main herd. Rations for each pen were adjusted daily to account for cows that were removed from the pen as they calved. Cows that were fed pine needles were all treated for retained placenta after calving with injections of a prostaglandin and an antibiotic (2 mL of Bovalene®, Syntex, West Des Moines, IA, and 50 mL of LA200®, Pfizer, New York, NY).

The cattle portion of this experiment was conducted at the Ft. Keogh Livestock and Range Research Laboratory, Miles City, MT. Eighteen pregnant cows that had breeding dates recorded were started on the study at 250 d (range = 247 to 253) of pregnancy and were assigned at random to be controls or to be fed pine needles. Eleven controls were fed 8.1 kg·animal^{-1}·d^{-1} of hay, and seven treated cows were fed 2.25 kg·animal^{-1}·d^{-1} of pine needles and 4.9 kg·animal^{-1}·d^{-1} of hay. Both rations were group-fed. The pine needles were from the same collection batch that was used to feed the buffalo. Cows were removed from the experiment as they aborted or calved, and the amount of ration was adjusted each day for the number of cows present.

Experiment 4

This experiment was conducted to determine whether feeding smaller amounts of pine needles would cause abortions and whether prefeeding of these smaller amounts would affect the abortion response when larger amounts were fed. Thirty crossbred cows were assigned at random to one of four treatments. Cows in two treatments (A and B) were fed pine needles for 40 d starting at 215 d (range = 209 to 221) of pregnancy. Groups A and B were fed .11 and .34 kg·animal^{-1}·d^{-1} of ground needles, respectively. These amounts of pine needles were fed in addition to a basal diet of 20 kg·animal^{-1}·d^{-1} of corn silage (wet weight). The other two treatments (C and D) were fed only the basal diet during this period. At 255 d (range = 252 to 258) of pregnancy, the amount of pine needles was increased to 1.35 kg·animal^{-1}·d^{-1} for both Groups A and B. Group C was a positive control group and was started on the 1.35-kg level of pine needle feeding at this time. Group D was a negative control group and was continued on the basal diet. The three groups that were fed pine needles (A, B, and C) were fed the basal diet at the rate of 18 kg·animal^{-1}·d^{-1} to maintain a constant dry matter intake. Cows were removed from the experiment as they aborted or calved, and the amount fed was adjusted daily for the number of cows present. The feeding of pine needles was stopped after 14 d for any cows that had not calved by that time.

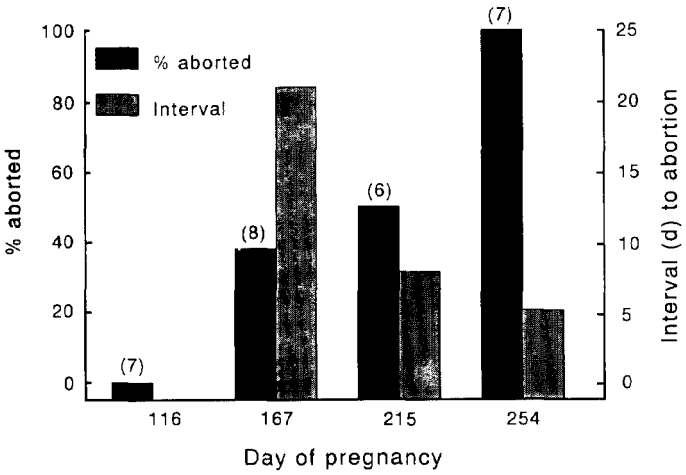

Figure 1. Effect of stage of pregnancy on abortion response of cows fed pine needles (Exp. 1). Percentage of cows that aborted is shown on the left axis, and interval from the start of pine needle feeding to abortion is shown on the right axis. Total numbers of cows at each stage are shown in parentheses. Pooled SE for interval to abortion is 8.3 d.

Results

Experiment 1

The results of this study are summarized in Figure 1. None of the cows from the 116-d group aborted. Beyond 116 d, there was a linear increase ($P < .05$) in the percentage of cows that aborted after they had consumed pine needles, and a concurrent linear decrease ($P < .05$) in the interval to abortion. Of the 15 cows that did not abort, one had live twins at 266 d, and the others had single live calves at normal gestation lengths (284 ± 4 d). The calves from cows that aborted were all alive at birth except for one partially mummified fetus delivered 41 d after the start of pine needle feeding in the 157-d group. All aborted calves from the last group survived, but no calves from the earlier groups survived. All cows that aborted had retained placenta, but there were no observed problems due to toxic reactions to the pine needles or to the retained placenta.

Experiment 2

Results of this experiment are summarized in Table 1. The feeding of pine needles starting at 250 d of pregnancy induced an abortion in most cows (0/14, control vs 27/30, pine needles, $P < .01$); there was only a slight increase in the percentage that aborted by increasing the amount of pine needles fed from .7 to 1.4 or 2.7 kg·animal^{-1}·d^{-1}. Increasing the amount of pine needles fed had a greater effect on interval to abortion than on percentage

Table 2. Interval (d) to calving in buffalo and cattle as affected by feeding pine needles (Exp. 3)

	Buffalo[a]			Cattle[a]		
Treatment	n	Days	Range	n	Days	Range
Control	6	23.0 ± 5.2	16 to 28	11	32.6 ± 4.2	24 to 39
Pine needle[b]	6	7.7 ± 1.4	5.5 to 9	7	5.1 ± 2.3	3 to 10

[a]Control vs pine needle within species ($P < .01$).
[b]Pine needle-fed, buffalo vs cattle ($P < .05$).

that aborted. The effect on interval was a linear decrease as amount fed increased ($P < .01$). Feeding pine needles for only 1 or 3 d caused some abortions (1/9 and 3/10, $P < .05$), but the response was less than when the needles were fed for 21 d (4/19 vs 10/10, $P < .01$). Injecting vitamin A before feeding pine needles did not prevent abortion (83 vs 100%, $P > .25$). All cows that aborted had retained placenta, but all calves were born alive. Pregnancy data from the subsequent breeding season were available for 31 control cows and 20 cows previously fed pine needles that were all nursing calves. Pregnancy rate was not affected by feeding pine needles (87% for control vs 95% for pine needle-fed).

Feeding pine needles caused no abortions in sheep or goats. One control goat aborted during the experimental period. Sheep readily ate pine needles, but goats were more reluctant. The goats were supplemented with freely available whole needles, which they ate more readily than those needles ground and mixed with hay. In both sheep and goats, the amount of needles eaten should have been sufficient to cause a response, because they were eating a dietary percentage that caused a marked response in cattle. No toxic or unusual effects were observed in either goats or sheep.

Experiment 3

Results of this experiment are summarized in Table 2. Feeding pine needles decreased ($P < .01$) the interval to parturition in both buffalo and cattle. In both species all calves were born alive, but all cows that were fed needles had retained placenta. No complications related to retained placenta were observed. One 3-yr-old buffalo had little milk and would not accept her calf, so the calf was bottle-fed and sold. Two calves from the cattle fed pine needles died shortly after birth. Buffalo had a slightly longer interval to calving after they had consumed pine needles than did cattle ($P < .05$).

Experiment 4

Results of Exp. 4 are summarized in Table 3. Feeding pine needles at the rate of 1.3 $kg \cdot animal^{-1} \cdot d^{-1}$ shortened the interval to parturition ($P < .01$). Neither of the prefeeding treatments induced abortion. The primary effect of the pine needle prefeeding was that the .34-kg treatment delayed abortion after the higher levels of pine needles were fed (B vs C, $P < .01$). Any cow that calved during the period of pine needle feeding was classified as having an abortion. Two of eight cows in Group A and one of six cows in Group B did not abort, but those ratios did not differ from that in Group C, in which none of the eight cows aborted. All cows that aborted had live calves and retained placenta.

Discussion

The results of these experiments agree with several reports (see review by James et al., 1989) that consumption of needles from Ponderosa pine causes premature parturition or abortion. Considerable variation exists in abortion response, both in field and controlled experimental conditions (James et al., 1989). A purpose of these studies was to generate some information on why variability exists.

Ranchers that have problems with pine needle-induced abortion in their cattle report that problems occur in January and February; some occurred as early as November or December. Most cows in the region that contains Ponderosa pine are bred in May through August. These cows would become susceptible to pine needle abortion between 5 and 6 mo of gestation, with maximum susceptibility at 7 or 8 mo (Exp. 1). Even if they consume pine needles, they are not susceptible. This explains why cows do not abort before early winter. Unfortunately, we know little about consumption patterns of pine needles throughout the year and what variables affect consumption (Short et al., 1991; Pfister and Adams, 1992).

Some variability in response can be explained by the dose effect observed in Exp. 1 and 4. A minimum intake of approximately .68 kg of needles must be attained for several days to induce abortion. Greater amounts will induce abortion in a shorter time. Lack of abortion problems when cows are eating pine needles could be attributed

Table 3. Effect of prefeeding low levels of pine needles (PN) on interval to parturition (Exp. 4)

Pretreatment	Treatment[a]	All cows n	All cows Days[b]	All cows Range	Cows that aborted n	Cows that aborted Days[c]	Cows that aborted Range
.1 kg of PN	1.3 kg of PN(A)	8	10.7 ± 13.0	3 to 37	6	3.9 ± 1.6	3 to 7
.3 kg of PN	1.3 kg of PN(B)	6	16.4 ± 9.9	9 to 36	5	12.5 ± 2.8	9 to 15
None	1.3 kg of PN(C)	8	5.5 ± 3.2	2 to 11	8	5.5 ± 3.2	2 to 11
None	None (D)	8	34.6 ± 4.2	26 to 39	8	34.6 ± 4.2	26 to 39

[a]Treatment abbreviations shown in parentheses.
[b]A,B,C vs D ($P < .01$); B vs C ($P < .05$); pooled SE = 8.5.
[c]A,B,C vs D ($P < .01$); B vs C ($P < .01$); pooled SE = 3.2.

to insufficient consumption levels. There was no evidence in these studies that injecting vitamin A will prevent abortions caused by pine needles. Observations by ranchers that this practice works were probably confounded by other management changes concurrent with the injection of vitamin A.

We speculated in an earlier report that variation in response may be caused by variation in the content of abortifacient compound(s) in needles (James et al., 1989). More recent and comprehensive results from the experiments reported here and elsewhere (Miner et al., 1987; Panter et al., 1991; Short et al., 1991) showed a consistent abortion response of cows to pine needles. This consistency occurred with needles collected from a variety of sources that differed in location (six different ranches in Montana and Oregon), season, year, and type of needle (weathered vs fresh). Therefore, our present conclusion is that content of the abortifacient material in pine needles is consistent across locations and time. Variations in response of cows are more likely caused by variations in intake and(or) stage of pregnancy.

There has been some speculation that pine needles have a direct toxic effect on the cow and(or) calf (James et al., 1989), as evidenced by cow and calf deaths and low rebreeding rates of affected cows. There was no evidence of toxicity to the calf. All calves (except one mummified fetus) were alive at the time at birth, and calf survival was dependent on maturity at the time of parturition. No toxic effects were observed in cows. All cows survived and subsequent fertility was not affected by the induced parturition. Panter et al. (1990) found a direct toxic effect of feeding branch tips, but that effect could be caused either by much higher concentrations of the abortifacient compound or the presence of a compound in the branch tips that differs from that in the needles.

We must emphasize that prophylactic treatments were used to minimize complications from retained placenta. Several studies (see review by Paisley et al., 1986) have shown that the appropriate treatment for retained placenta is not to remove the retained placenta manually or give intrauterine treatments. The best approach is to give a systemic prophylactic treatment of antibiotics to prevent uterine infections.

Feeding pine needles to buffalo caused abortions, as in cattle. Buffalo do not provide an alternative experimental model for cattle because their response is the same as that of cattle. However, buffalo may still be considered as an alternate grazer in areas with pine trees. Available field evidence indicates that buffalo grazing in areas with pine trees have normal calving rates; we speculate that they do not consume needles. Sheep and goats do not abort in response to consumption of pine needles and may provide clues to the mechanisms involved with abortion caused by pine needles. Differences among sheep, goats, and cattle in digestion, metabolism, and(or) pregnancy maintenance may help us to understand the abortifacient mechanism(s).

Differences between cattle and buffalo in interval to abortion were probably due to experimental protocol differences. Cattle were fed 2.25 kg per animal of pine needles at the start of the study, whereas buffalo were initially fed .45 kg of pine needles, and this amount was increased to 2.25 kg over several days. As might be expected with an induced physiological event such as this, the variability in interval to calving was decreased by the feeding of pine needles. The variability of the control buffalo was surprisingly low considering that we did not know breeding dates for those cows. Apparently, the buffalo conceived over a short time and(or) had a small natural variation in gestation length.

Failure to find any effects of pine needles in goats and sheep agrees with other work (Panter et al., 1987; James et al., 1989). Therefore, goats and sheep could be an alternative to cattle when pine needle abortion is a potential problem. Some degree of caution should be exercised when considering using sheep or goats because these experiments have been conducted under a limited set of conditions. Sheep and goats may be useful in studies to determine mechanisms of pine nee-

dle-induced abortion because these species are similar to cattle and buffalo in terms of digestion and pregnancy.

Buffalo is the first species of grazing ruminants other than cattle that has been shown to be affected by pine needles. Buffalo and cattle are similar genetically (the two species will interbreed), in gestation length (283 d), and in placental type (convex cotyledonary), whereas deer, goats, and sheep have shorter gestation lengths (200 d for mule deer and whitetail deer and 150 d for goats and sheep) and slightly different placental types (concave cotyledonary). The failure of sheep, goats, and deer to respond to pine needles may be related to these differences or to other differences not yet identified.

The apparent mechanism involved in abortions caused by pine needles is an interruption in the blood flow to the uterus (Christenson et al., 1992a,b; Ford et al., 1992). Vitamin A is apparently not involved with this mechanism, and somehow only cattle and buffalo are susceptible. Prefeeding a low amount (.34 kg) of pine needles for 40 d before starting a higher amount will delay parturition induced by the higher amount fed. We speculate that prefeeding induces a compensatory mechanism for blood flow, but the compensation is not complete enough to override an abortifacient dose.

Implications

These studies help us to understand some of the variability in abortion response of cows to consumption of Ponderosa pine needles. Stage of pregnancy and amount of needles consumed are the main variables that affect the response of cows to consumption of pine needles. Producers should be aware of potential exposure to pine needles and manage cows to prevent consumption of pine needles after 5 mo of pregnancy. Buffalo, goats, and sheep can be alternate grazers in areas with Ponderosa pine, because buffalo apparently do not eat pine needles, and because goats and sheep do not abort even if they eat them.

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